# Proceedings of the eighteenth meeting of the Canadian Tree Improvement Association: Part 1

# Comptes rendus [illegible] conférence de[illegible] canadienne po[illegible] des arbres: 1re

Duncan, British Columbia
August 18-21, 1981
du 18 au 21 août 1981

# PROCEEDINGS

# OF THE

# EIGHTEENTH MEETING

# OF THE

# CANADIAN TREE IMPROVEMENT ASSOCIATION

## PART 1:

## MINUTES AND MEMBERS' REPORTS

HELD IN
DUNCAN, BRITISH COLUMBIA
AUGUST 18-21, 1981

EDITOR: C.W. YEATMAN

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Chalk River, Ontario K0J 1J0

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Ottawa, 1982

# COMPTES RENDUS

# DE LA

# DIX-HUITIÈME CONFÉRENCE

# DE

# L'ASSOCIATION CANADIENNE POUR L'AMÉLIORATION DES ARBRES

## 1RE PARTIE:

## PROCÈS-VERBAUX ET RAPPORTS DES MEMBRES

TENUE À
DUNCAN COLOMBIE-BRITANNIQUE
DU 18 AU 21 AOÛT 1981

RÉDACTEUR C.W. YEATMAN

1re partie. Procès-verbaux et rapports des membres.

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Ottawa, 1982

PROCEEDINGS OF THE EIGHTEENTH MEETING OF

THE CANADIAN TREE IMPROVEMENT ASSOCIATION

**With the compliments of the Association**

*Enquiries may be addressed to the authors or to* Mr. M.J. Coles, Executive Secretary, C.T.I.A./A.C.A.A., N.B. Executive Forest Research Committee Inc. 500 Beaverbrook Court, Fredericton, N.B. E3B 5X4.

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***The Ninteenth Meeting of the Association will be held in Toronto, Ontario, August 22-26, 1983. Speakers will be invited to address the topic of Vegetative Propagation and its Impact on Genetic Improvement and our Future Forests. Canadian and foreign visitors are welcome. Further information will be distributed in the fall 1982 to all members and to others on request. Enquiries concerning the 19th Meeting should be addressed to:*** Miss R.M. Rauter, Chairman, C.T.I.A./A.C.A.A., Forest Resources Branch, Ontario Ministry of Natural Resources, Parliament Buildings, Toronto, Ontario M7A 1W3.

---

**To:** *Dr. C.W. Yeatman, Editor, C.T.I.A./A.C.A.A.*
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*La dix-neuvième conference de l'Association aura lieu à Toronto, Ontario, du 22 au 26 Août 1983. Des orateurs seront invités à s'adresser au sujet de la propagation végétative et son impact sur l'amélioration génétique et sur nos forêts futures. Tous sont bienvenues. Des informations supplémentaires seront distribuées durant l'automne de 1982 à tous les membres et à tous ceux qui en feront la demande. Ces demandes de renseignements concernant la dix-neuvième réunion devrons être adressées à: Miss R.M. Rauter, Chairman, C.T.J.A./A.C.A.A., Forest Resources Branch, Ontario Ministry of Natural Resources, Parliament Buildings, Toronto, Ontario M7A 1W3.*

---

**À:** *Dr. C.W. Yeatman, éditeur, A.C.A.A./C.T.I.A.*
*Environnement Canada*
*Service canadien des forets*
*Institut forestier national de Petawawa*
*Chalk River, Ontario K0J 1J0*

**Nom:** *Prof.*
*Dr.* *Mme.*
*M.* *Mlle.* . . . . . .

**Adresse:** . . . . . .
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# ACTIVE MEMBERS

June 1982

## CANADIAN TREE IMPROVEMENT ASSOCIATION

| | |
|---|---|
| Mr. B. Adams | Project Forester<br>North Canadian Forest Industry<br>P.O. Box 100<br>Grand Prairie, Alberta, T8V 3A3 |
| Dr. J.D. Ambrose | University of Guelph<br>Arboretum<br>Guelph, Ontario, N1G 2W1 |
| Mr. D.J. Barker | T.M. Thomson & Associates<br>1006 Government Street<br>Victoria, B.C., V8W 1X7 |
| Dr. J.E. Barker | Western Forest Products<br>Lost Lake Seed Orchard<br>1020 Beckwith Avenue<br>Victoria, B.C., V8X 3S4 |
| Mr. C.A. Bartram | Silviculture Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |
| M. R. Beaudoin | Min. des Terres et Forests<br>Service de la Recherche<br>2700 Rue Einstein<br>Ste-Foy, Québec, G1P 3W8 |
| M. Jacques Bégin | Canadian International Paper Inc.<br>Sunlife Building<br>Montreal, Québec, H3B 2X1 |
| Mr. Robert P. Bettle | Department Natural Resources<br>Provincial Forest Nursery<br>R.R. 6<br>Fredericton, N.B., E3B 3P7 |
| Mr. P. Bizens | B.C. Forest Service<br>General Delivery<br>Tappen, B.C., V0E 2X0 |
| Mr. J.M. Bonga | Canadian Forestry Service<br>Maritimes Forest Research Centre<br>P.O. Box 4000<br>Fredericton, N.B., E3P 5P7 |

| | |
|---|---|
| Dr. R.C. Bower | MacMillan Bloedel Limited<br>65 Front Street<br>Nanaimo, B.C., V9R 5H9 |
| Dr. M.G. Boyer | Department of Biology<br>York University<br>4700 Keele Street<br>Downsview 463, Ontario, M3J 1P3 |
| Mr. T.J.B. Boyle | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |
| Dr. G.P. Buchert | Ontario Tree Improvement and Forest Biomass Institute<br>Ministry Natural Resources<br>Maple, Ontario, L0J 1E0 |
| Dr. W.M. Cheliak | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |
| Mr. J.F. Coles | N.B. Exec. For. Res. Comm. Inc.<br>500 Beaverbrook Court<br>Fredericton, N.B., E3B 5X4 |
| Dr. Armand G. Corriveau | Centre de recherche forestières des Laurentides<br>Service canadien des forêts<br>C.P. 3800, Ste-Foy<br>Québec 10, P.Q., G1V 4C7 |
| Mr. M. Crown | B.C. Forest Service<br>Box 816<br>Duncan, B.C., V9L 3Y2 |
| Dr. B. Dancik | Department of Forest Science<br>University of Alberta<br>720 Chem-Min Eng Building<br>Edmonton, Alberta, T6G 2G6 |
| Dr. A.L. D'Aoust | Centre de recherche forestières des Laurentides<br>C.P. 3800, Ste-Foy<br>Québec 10, P.Q., G1V 4C7 |
| Dr. Narinder K. Dhir | Reforestation & Reclamation Branch<br>Alberta Forest Service<br>9915-108 Street<br>Edmonton, Alberta<br>T5K 2C9 |

| | |
|---|---|
| Mr. G. Dunsworth | Alberta Forest Service<br>Energy and Natural Resources<br>Petroleum Plaza<br>South Tower<br>Edmonton, Alberta, T5K 2C9 |
| Dr. D.G. Edwards | Pacific Forest Research Centre<br>Canadian Forestry Service<br>506 West Burnside Road<br>Victoria, B.C., V8Z 1M5 |
| Dr. Y. El-Kassaby | Faculty of Forestry<br>University of B.C.<br>Vancouver, B.C., V6T 1W5 |
| Dr. J.L. Farrar | Faculty of Forestry<br>University of Toronto<br>Toronto, Ontario, M5S 1A1 |
| Ms. Anita M.K. Fashler | Pacific Logging Company Limited<br>8067 East Saanich Road<br>Saanichton, B.C., V05 1M0 |
| Dr. W.H. Fogal | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |
| Dr. D.P. Fowler | Maritimes Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 4000<br>Fredericton, N.B., E3B 5P7 |
| Dr. D.A. Fraser | Department of Geography<br>Concordia University<br>1435 Drummond Street<br>Montreal 107, Québec, H3G 1W4 |
| Dr. R. Girouard | Centre de recherche forestières des Laurentides<br>Service canadien des forêts<br>C.P. 3800, Ste-Foy<br>Québec 10, P.Q., G1V 4C7 |
| Dr. A.G. Gordon | Ontario Ministry of Natural Resources<br>Central Forest Resource Unit<br>Box 490<br>Sault St. Marie, Ontario, P6A 3M7 |

| | |
|---|---|
| Dr. J.P. Hall | Newfoundland Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 6028<br>St. Johns, Newfoundland, A1C 5X8 |
| Mr. R. Hallett | Maritimes Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 4000<br>Fredericton, N.B., E3B 5P7 |
| Mr. J.C. Heaman | Research Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |
| Mr. C. Hewson | Silviculture Branch<br>Red Rock Nursery<br>B.C. Ministry of Forests<br>R.R. 7 Mile Road<br>Prince George, B.C., V2N 2J5 |
| Dr. R.H. Ho | Ontario Tree Improvement and Forest Biomass Institute<br>Ministry Natural Resources<br>Maple, Ontario, L0J 1E0 |
| Mr. J.V. Hood | Ontario Tree Improvement and Forest Biomass Institute<br>Ministry Natural Resources<br>Maple, Ontario, L0J 1E0 |
| Mr. K. Illingworth | Research Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |
| Mr. B. Jaquish | B.C. Ministry of Forests<br>3806-38 Street<br>Vernon, B.C., V1T 7L2 |
| Mr. S.E.T. John | Canadian Forest Products<br>R.R. 1 Chapman Road<br>Sechelt, B.C. |
| Mr. Ingemar Karlsson | Cowichan Lake Forest Experiment Station<br>Research Branch<br>Ministry of Forests<br>Mesachie Lake P.O.<br>B.C., V0R 2N0 |

| | |
|---|---|
| Dr. M.A.K. Khalil | Newfoundland Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 6028<br>St. Johns, Newfoundland, A1C 5X8 |
| Mr. G.K. Kiss | Vernon Research Station<br>B.C. Ministry of Forests<br>3401 Reservoir Road<br>Vernon, B.C., V1B 2C7 |
| Dr. J.I. Klein | Northern Forest Research Centre<br>Canadian Forestry Service<br>5320-122 Street<br>Edmonton, Alberta, T6H 3S5 |
| Dr. Margaret H. Knowles | School of Forestry<br>Lakehead University<br>Thunder Bay, Ontario, P7B 5E1 |
| Mr. J. Konishi | Silviculture Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |
| M. Yves Lamontagne | Min. des Terres et Forêts<br>Service de la restauration<br>200 B Chemin Ste-Foy<br>Québec, P.Q., G1R 4X7 |
| Dr. D.T. Lester | Crown Zellerbash (Canada)<br>P.O. Box 368<br>Wilsonville, Oregon 97070 |
| Dr. S. Manley | P.E.I. Department Agriculture and Forestry<br>P.O. Box 2000<br>Charlottetown, P.E.I., C1A 7N8 |
| Mr. D.M. Matthews | Canadian International Paper Company<br>Dalhousie, N.B., E0K 1B0 |
| Dr. Jack Maze | Department of Botany<br>University of British Columbia<br>2075 Westbrook Mall<br>Vancouver, B.C., V6T 1W5 |
| Mr. T.M. McDonough | Department Forest Research & Lands<br>P.O. Box 616<br>Grand Falls, Newfoundland, A2A 2K2 |

| | |
|---|---|
| Dr. M.D. Meagher | Research Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |
| Mr. L.K. Miller | Ministry Natural Resources<br>60 Wilson Avenue<br>Timmins, Ontario, P4N 2S7 |
| Dr. E.K. Morgenstern | Department of Forest Resources<br>University of New Brunswick<br>Bag No. 44555<br>Fredericton, N.B., E3B 6C2 |
| Mr. M.A. Mubareka | Fraser Company Limited<br>27 Rice Street<br>Edmundston, N.B., E3V 1S9 |
| Mr. T.J. Mullin | Tree Breeding Centre<br>Department of Lands and Forests<br>Debert, Nova Scotia, B0M 1G0 |
| Dr. Gordon Murray | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |
| Mr. R.J. Orynik | Prince Albert Pulpwood<br>P.O. Box 1720<br>Prince Albert, Saskatchewan, S6V 5T3 |
| Dr. Y.S. Park | Maritimes Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 4000<br>Fredericton, N.B., E3B 5P7 |
| Dr. William H. Parker | Department of Biology<br>Lakehead University<br>Thunder Bay, Ontario, P7B 5E1 |
| Dr. Louis Parrot | Faculte de forestièrie et de Géodésie<br>Université Laval<br>Québec, P.Q., G1K 7P4 |
| Dr. R.P. Pharis | Department of Biology<br>University of Calgary<br>2920 24th Avenue N.W.<br>Calgary, Alberta, T2N 1N4 |
| Mr. Jack A. Pitel | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |

| | |
|---|---|
| Dr. D.F.W. Pollard | 19th Floor Place Vincent Massey<br>Hull, Québec<br>K1A 1G5 |
| Dr. G.R. Powell | Department of Forest Science<br>University of New Brunswick<br>P.O. Box 4400<br>Fredericton, N.B., E3B 5A3 |
| Ms. Rose Marie Rauter | Forest Resources Branch<br>Ontario Ministry of Natural Resources<br>Parliament Buildings<br>Toronto, Ontario, M7A 1W3 |
| Mr. D. Robert | C.P. 283<br>St. Louis de Pintendre<br>Québec, P.Q., G0R 2K0 |
| Mr. S. Robertson | Newfoundland Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 6028<br>St. John's, Newfoundland, A1C 5X8 |
| Ms. Diane Roddy | Prince Albert Pulpwood Ltd.<br>P.O. Box 1720<br>Prince Albert, Saskatchewan, S6V 5T3 |
| Dr. W.G. Ronald | Canada Department Agriculture<br>Research Station<br>Morden, Manitoba, R0G 1J0 |
| Dr. S.D. Ross | Ministry of Forests<br>Research Branch<br>North Road Lab<br>Victoria, B.C., V8Z 5J3 |
| Ms. Janet Schilf | Alberta Forest Service<br>Reforest and Recl Branch<br>Petroleum Plaza South<br>9915-108 Street<br>Edmonton, Alberta, T5K 2C9 |
| Mr. S. Segaran | Forestry Branch<br>Department of Natural Resources<br>300-530 Kenaston Blvd.<br>Winnipeg, Manitoba, L3N 1Z4 |
| Mr. Dale Simpson | Maritimes Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 4000<br>Fredericton, N.B., E3B 5P7 |

| | |
|---|---|
| Mr. D.A. Skeates | Ontario Tree Improvement and Forest Biomass Institute<br>Ministry Natural Resources<br>Maple, Ontario, L0J 1E0 |
| Mr. R.F. Smith | Maritimes Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 4000<br>Fredericton, N.B., E3B 5P7 |
| M. A. Stipanicic | Min. des Terres et Forêts<br>Service de la recherche<br>2700 Rue Einstein<br>Ste-Foy, Québec, G1P 3W8 |
| Dr. O Sziklai | Faculty of Forestry<br>University of B.C.<br>Vancouver 8, B.C., V6T 1W5 |
| Mr. J. Thompson | Saskatchewan Department Renewable Resources<br>Silviculture Section<br>Prince Albert, Saskatchewan, S6V 1B5 |
| Dr. G. Vallée | Service de la recherche<br>Min. des Terres et Forêts<br>2700 Rue Einstein<br>Ste-Foy, Québec, G1P 3W8 |
| Mr. W. Van Borrendam | Ontario Tree Improvement and Forest Biomass Institute<br>Ministry Natural Resources<br>Maple, Ontario, L0J 1E0 |
| Mr. B.S.P. Wang | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |
| Mr. Ronald G. Wasser | Sussex Tree Nursery<br>R.R. 4<br>Sussex, N.B., E0E 1P0 |
| Dr. J.E. Webber | Research Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |

| | |
|---|---|
| Dr. C.W. Yeatman | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |
| Dr. F. Yeh | Research Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |
| Dr. Cheng Ying | Research Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |
| Mr. D. Young | Procter and Gamble<br>Cellulose Limited<br>Box 1029<br>Grand Prairie, Alberta, T8V 3A9 |
| Dr. L. Zsuffa | Ontario Tree Improvement and Forest Biomass Institute<br>Ministry Natural Resources<br>Maple, Ontario, L0J 1E0 |
| Mr. M.B. Barkhouse | Silviculture Forester<br>Bowater Mersey Paper Co.<br>P.O. Box 1150<br>Liverpool, N.S., B0T 1K0 |
| Mr. B. Phillion | Ministry of Natural Resources<br>Orono Tree Nursery<br>Orono, Ontario, L0B 1M0 |

## BUSINESS MEETING - MINUTES

J.C. Heaman chaired the 18th Business Meeting of the C.T.I.A./ A.C.A.A. which was called to order at 8:45 p.m. August 19, 1981.

207. MINUTES OF THE LAST MEETING

Motion: That the minutes of the 17th meeting be adopted as published.

Moved by B.S.P. Wang, seconded by J. Thompson. Carried.

208. MEMBERSHIP

The following nominees for Sponsoring and Active membership were presented:

a) New Members

1) Sponsoring

| | |
|---|---|
| Mr. F.L.C. Reed | Assistant Deputy Minister<br>Canadian Forestry Service<br>Ottawa, Ontario |

2) Active

| | |
|---|---|
| Dr. J.E. Barker | Western Forest Products |
| Mr. C.A. Bartram | B.C. Ministry of Forests |
| Mr. J. Bégin | Canadian International Paper Co. |
| Mr. R.D. Bettle | N.B. Dept. of Natural Resources |
| Mr. P. Bizens | B.C. Ministry of Forests |
| Mr. T.J.B. Boyle | Canadian Forestry Service |
| Mr. W. Cheliak | Canadian Forestry Service/University of Alberta |
| Dr. U. El-Kassaby | University of British Columbia |
| Dr. R. Ho | Ontario Ministry of Natural Resources |
| Mr. J. Hood | Ontario Ministry of Natural Resources |
| Mr. B. Jaquish | B.C. Ministry of Forests |
| Ms. S.E.T. John | Canadian Forest Products |
| Dr. M.H. Knowles | Lakehead University |
| Dr. D.T. Lester | Crown Zellerbach |
| Dr. J. Maze | University of British Columbia |
| Mr. L.K. Miller | Ontario Ministry of Natural Resources |
| Mr. M.A. Mubareka | Fraser Company |
| Dr. W.H. Parker | Lakehead University |
| Ms. D. Roddy | Prince Albert Pulpwood Ltd. |
| Dr. S.D. Ross | B.C. Ministry of Forests |
| Mr. D. Simpson | Canadian Forestry Service |
| Mr. R.G. Wasser | Irving Company |

3) Corresponding

The names of 66 new Corresponding Members were added to the list of Canadian addressees during 1979-81.

b) Change of Status from Active to Corresponding

A.C. Carlisle
K.C. Eng

c) Change of Status from Corresponding to Active

Mr. W.D. Baker
Mr. G. Dunsworth
Ms. Anita M.K. Fashler

Motion: That the prospective members (as listed) be duly elected.

Moved by K. Illingworth, seconded by D. Winston. Carried.

209. FINANCIAL STATEMENT

Financial statement prepared by C.W. Yeatman, Editor/Treasurer, was tabled for membership information and acceptance. It showed that as of July 29, 1981 the Association's account had a balance of $2,411.56.

Motion: That the financial statement as presented be accepted.

Moved by J.I. Klein, seconded by E.K. Morgenstern. Carried.

210. FINANCIAL CONTRIBUTIONS FOR THE 1981 SYMPOSIUM

J.C. Heaman explained that the forest industries and provincial Forest Services in B.C. and Alberta were approached for contributions to pay for travelling expenses of several invited symposium speakers. A total amount of $2,895.00 was kindly contributed by the following organizations.

British Columbia

British Columbia Forest Products Ltd.
Canadian Forest Products Ltd.
Crown Zellerbach Canada Ltd.
MacMillan Bloedel Ltd.
Northwood Pulp and Timber Ltd.
Pacific Forest Products Ltd.
Tahsis Company Ltd.
Weldwood of Canada Ltd.
West Fraser Mills Ltd.

Alberta

Alberta Forest Service
Canadian Forest Products Ltd., Alberta Operations
Procter and Gamble Cellulose Ltd.
St. Regis (Alberta) Ltd.

The membership expressed gratitude for the generous contributions provided by these organizations. Gratitude was also expressed for the luncheons provided by the Government of British Columbia and by the Research Branch of the B.C. Ministry of Forests.

211. EDITOR'S REPORT

The report of the Editor (C.W. Yeatman) outlining concerns and suggestions on publication of C.T.I.A./A.C.A.A. proceedings, membership and distribution list, and constitution and bylaws was presented for information and discussion. It was noted with appreciation that the Canadian Forestry Service will continue to publish the Proceedings, parts 1 and 2. However, constitution and bylaws and membership and distribution list will have to be published by the Association itself. The desirability of continuing to print and distribute the membership directory and list of foreign addressees was discussed and debated. It was finally agreed that the next executive should consider the cost and desirability of publishing and distributing the directory and make the appropriate decision.

The report noted that the number of Canadian addressees in July 1981 stood at 428, including 6 Honorary members, 24 Sponsoring members, 83 Active members, 204 Corresponding members and 110 libraries and institutions. In addition, foreign addressees included 184 in the United States and some 219 in other countries around the world. Members were reminded and requested to send corrections and additions to the Editor as they occur.

212. BUSINESS ARISING FROM PREVIOUS MEETINGS

a) EDUCATION COMMITTEE AND SCHOLARSHIP FUND

The report prepared by C.W. Yeatman of the Standing Committee on Forest Education appointed by the 17th meeting of the Association was read by F. Yeh. The Committee was formed to draw up terms of reference for a Forest Genetics Scholarship Fund in accordance with the motion (item 192) approved at the Association's 16th meeting. The Committee was instructed (item 200c): (a) to complete, if possible an agreement on terms of reference with appropriate co-sponsors for ratification by the Association's executive and subsequently, (b) to solicit contributors for the Scholarship Fund in accordance with the accepted terms of reference.

F. Yeh informed members that the Committee's efforts to find appropriate co-sponsor(s) were not successful; Canadian Pulp and Paper Association, Canadian Forestry Association, and Canadian Institute of Forestry were approached. Although there was widespread support for creating a scholarship fund, prospects for establishing it were not encouraging. Considerable discussion took place with members speaking both in favor and against continuing efforts to establish scholarship fund. Support was also voiced in favor of a proposal communicated in a letter by C.W. Yeatman suggesting that C.T.I.A./A.C.A.A. should take on a functional project in education and establish a prize or a scholarship. It was decided that the next executive consider various alternatives to continue the Association's involvement in improving quality of forest genetics education and training in Canada and decide on an appropriate course of action that may best serve this objective.

b) CONSTITUTION AND BYLAWS

N. Dhir informed members that the Constitution and Bylaws incorporating amendments approved by the 17th meeting of the Association had been printed and distributed to membership.

213. FUTURE MEETINGS

a) LOCATION OF 1983 MEETING

The chairman called to attention the resolution passed by the 17th meeting which stated that the 19th meeting of the Association be held in Ontario in 1983. R.M. Rauter confirmed that the Ontario Ministry of Natural Resources will host the meeting which will be held at Maple/Toronto.

The possibility of joint meeting in 1983 with North Central Tree Improvement was also explored (item 202e). However, it was learned that NCTIA had decided to hold its 1983 meeting at Wooster, Ohio and invited C.T.I.A./A.C.A.A. to coordinate meeting dates and programs in a manner that participants at both C.T.I.A./A.C.A.A. and NCTIA meetings can have opportunity to attend the two meetings. The invitation was well received and it was decided that next executive should discuss meeting dates and programs with the NCTIA to see if it can be arranged.

b) THEME FOR 19TH MEETING

Suggestions were asked for the symposium theme for the 19th meeting. These were: (1) indepth consideration of alternate breeding strategies (Rauter), (2) genetic improvement strategies in vegetative propagation production systems (Klein), (3) correspondence of realized genetic gains with predicted genetic gains (Jensen), (4) genetic improvement of hardwoods (Morgenstern), (5) provenance research: critical values related to tree breeding (Yeh). It was decided that the new executive take these suggestions into consideration to decide an appropriate theme for the 1983 meeting.

c) LOCATION OF 1985 MEETING

In accordance with the suggestions discussed at the 16th and 17th meetings, invitations were received from Nova Scotia Dept. of Lands and Forests for holding the meeting in Nova Scotia, and from Le Comité de recherche en génétique et amélioration forestières for holding the meeting in Québec City, Québec. The general consensus was that the 1985 meeting be held in Québec.

Motion: That the invitation from Le Comité de recherche en génétique et amélioration forestières to hold 20th meeting of C.T.I.A./A.C.A.A. in Québec City be accepted.

Moved by M. Crown, seconded by J. Bégin. Carried.

d) LOCATION OF 1987 MEETING

Suggestions were requested for possible locations for 1987 meeting. G. Kiss suggested Vernon, B.C.; T. Mullin suggested Nova Scotia; J. Klein suggested Edmonton, Alberta.

214. ELECTION OF OFFICERS

K. Illingworth and E.K. Morgenstern were appointed as nominating committee and proposed the following slate of officers:

| | |
|---|---|
| Chairman | Miss R.M. Rauter |
| Vice-chairman | Dr. L. Zsuffa |
| Vice-chairman (Local Arrangements) | Mr. J. Hood |
| Executive Secretrary | Mr. J. Coles |
| Editor/Treasurer (see item 215b,c) | Dr. C.W. Yeatman |

Additional nominations were called from the floor, but none were received.

Motion: That the slate of officers proposed by the nominating committee be elected.

Moved by K. Illingworth, seconded by O. Sziklai. Carried.

215. NEW BUSINESS

a) SEED REGULATIONS

D. Pollard briefly described a proposal for suggested involvement of C.T.I.A./A.C.A.A. in setting certain technical standards for Seed Regulations as part of Canada Seed Act.

Motion: That the Executive of C.T.I.A./A.C.A.A. appoint a sub committee to: (1) study the proposed regulations for forest tree seeds pertaining to the Canada Seeds Act, (2) appraise the proposed role of the C.T.I.A. in establishing standards

for these Regulations, and (3) make recommendations to the Executive for further action.

Moved by D. Pollard, seconded by J. Klein. Carried.

b) AMENDMENTS TO CONSTITUTION AND BYLAWS (1981)

Motion: That the C.T.I.A./A.C.A.A. Constitution and Bylaws be amended by inserting the word underlined in Article IV.a and adding Article V.g. as follows:

Article IV.
Executive
a. The Executive of ... an Executive Secretary, an Editor and a Treasurer

Article V.
g. Treasurer

The Treasurer shall take office upon completion of the meeting which elected the new Executive. The Treasurer shall be responsible for receiving and distributing funds on behalf of the Association, and for maintaining accurate and up-to-date records of Association's accounts.

Moved by J. Klein, seconded by A. Gordon. Carried.

c) ELECTION OF TREASURER

Nominations for Treasurer were invited from the floor. Only one nomination was received, that of Dr. C.W. Yeatman.

Motion: That Dr. C.W. Yeatman be elected as Treasurer of C.T.I.A./A.C.A.A.

Moved by A. Gordon, seconded by G. Edwards. Carried.

216. ADJOURNMENT

Motion: That the 18th Business Meeting of the C.T.I.A./A.C.A.A. be adjourned.

Moved by G. Kiss, seconded by G. Edwards. Carried.

Narinder K. Dhir
Executive Secretary

# FIELD TRIPS
# VANCOUVER ISLAND
# AUGUST 1981

# C.T.I.A. / A.C.A.A. FIELD TRIP '81

"Any more smart questions?" HEATHER RUTHERGLEN (B.C. Forest Service) explains the Seed Extraction Plant at Duncan.

"Come on, get moving." HENNING JENSEN (B.C. Forest Service) herds his group around Koksilah Seed Orchard.

"The evidence is overwhel . . . " CHRIS HEAMAN describes progeny tests at Cowichan Lake Experiment Station.

"Gee, I wonder if they will grow in Ontario." MARIE RAUTER and BEN WANG at Cowichan Lake.

# VANCOUVER ISLAND, B.C.

"Tell us another one." BOB ACKERMAN, OLA ROSVALL (Sweden), JERRY KLEIN, HANS VAN BUIJTENEN (Texas A&M), CHRIS MORGENSTERN, RON SMITH et al. at Mount Newton Seed Orchard.

"My glasses are here somewhere." ROY FAULKNER (British Forestry Commission) prepares to launch into the keynote speech.

"Pst! Beer's at back." WILLARD FOGAL (right) among friends at Saanichton Seed Orchard.

"This one we stole from Koksilah." DIANA ANDREW (Pacific Forest Products) and ALAN ORR-EWING admire contents of the Saanichton Seed Orchard, with JOHN CONWAY, LORNE BRACE, MIKE CROWN, and BRUCE DEVITT.

## COWICHAN LAKE RESEARCH STATION

On the second afternoon, the members toured the British Columbia Ministry of Forests' Research Station and propagation centre at Cowichan Lake.

The Research Station was established in 1929 and was used initially for silvicultural projects; thinning, site classification and cone crop surveys. A camp was built to include bunkhouse and cook house to serve as a base for Reforestation Division's planting and snag-falling projects in the 1950's and early 1960's. These facilities are now maintained by Research Branch to provide accommodation and meals for visiting tours, training sessions and Ministry of Forests' field crews. The Federal Forestry Service also established a field laboratory there for studies of entomology and pathology but this is no longer in use. When Dr. Alan Orr-Ewing, the first tree breeder in British Columbia, started to accumulate material for tree improvement work in Douglas fir in the 1950's, the Research Station became the centre for much of this work and propagation of grafted and seedling material became a major function. A nursery was started to raise stock for progeny tests and research projects and a greenhouse was added later for container stock production. Each year since 1975 for example about 50,000 controlled cross seedlings have been raised for the Douglas fir breeding project.

As the programs expanded work on the other species was started, including the raising of seedlings for provenance studies in Interior spruce, Douglas fir and lodgepole pine, open-pollinated progenies for the western hemlock program and the development of yellow cedar projects.

With the advent of the Coastal Tree Improvement Council in 1979, the decision was made that all propagation for the orchards managed within the Cooperative and for clone banks would be centered on the Research Station. The facilities were therefore greatly expanded and by 1981 propagation in eight species amounted to over 32,000 grafts and 74,000 cuttings, (which included 40,000 cuttings of yellow cedar for use directly in high elevation reforestation).

Apart from the nursery complex, the experimental area comprises the breeding collection of Douglas fir, both clone banks of material grafted from selected trees, and seedlings from throughout the species' range, which will be available for wider breeding studies. Alan Orr-Ewing's collection of inbred material and some examples of older progeny tests also are on the area, while research into rootstock origins, graft incompatibility testing and other studies, such as cone stimulation, make use of the facilities and material. A hedged orchard of yellow cedar is maintained to provide material for direct reforestation by cuttings; also a plantation of seedlings and cuttings, which will eventually be available as a seed source for this species, is on the Research Station.

While emphasis on tree improvement has increased, silviculture research has been continued with the old thinning plots being maintained and the establishment of permanent sample plots, on which managed-stand yield tables can be based. Site classification work has also continued, including permanent demonstrations for teaching purposes.

At a second segment of the Research Station in the North Arm forest a few km away, a breeding collection of lodgepole pine, early trials with Pacific silver fir and land clearing for major clone bank projects are located.

With a single afternoon and almost 200 members on the tour, planning the field trip to cover as many points as possible posed a challenge, but this was met by splitting the tour into three parts and rotating groups among all stops. The North Arm forest had to be left out altogether.

One group started at the nursery and propagation houses. Here the techniques used for the British Columbia programs were demonstrated and the alternatives discussed. The grafting methods and, in particular, the methods of handling the rootstock and the developing ramets before they are large enough to ship to the orchards led to lively discussion. The methods used to root yellow cedar for production planting provided a look at what was, to many people, an unfamiliar species for reforestation and use of the Spencer Le Maire containers, in which the cuttings are taken right to the field site without root disturbance, received special attention. A look at the long-season Styro 8 seedlings from controlled pollinated families from the Douglas fir breeding project provided an opportunity to outline the objectives and progress of that project. (Details of these projects appear in the members reports.)

A second group was taken first to the hedging orchard of yellow cedar, a new concept in our reforestation program. Yellow cedar is a minor reforestation species but it has an important function in management of high elevation sites on the coast. Seed procurement and handling present a problem (which may be overcome eventually through cone stimulation techniques), and tests are showing already that rooted cuttings, which can be obtained very successfully from young material, will grow well compared to seedlings. The "orchard" consists of rows of half-sib families from selected parents from throughout the zone of utilization. The seedlings are clipped into bushy form to increase the number of cuttings available and to maintain juvenility.

This group then went on to see plantations of Douglas fir, and the oldest clone banks in B.C., dating from 1956 and 1958. These, with the more recent grafting, provided the basis for discussion of graft incompatibility in the species and the work that Ingemar Karlsson (Manager of the Research Station) is doing to select more compatible sources of rootstocks. Successful cone and pollen stimulation through girdling was also demonstrated. Time permitted only a brief glimpse of the 1971 plantation of wide interracial crosses now showing clear differences in performance.

The third group started with the silvicultural projects, including the oldest thinning plots in Douglas fir on the Pacific coast (which were established by Schenstrom in 1929), the fertilizer and thinning regimes of recently-established plots for the managed-stand-yield-tables, and finally a view of two selected plus tree parents used in the Douglas fir breeding program. These provided a basis for discussion of the selection criteria and an appraisal of the parent material needed for any breeding program.

The objective of the tour was to expose the members to the work at the Cowichan Lake Research Station, and while raising unanswered questions, it at least provided a physical picture of the tree improvement work that can be followed in detail in the members' reports and their publications. The tour also provided a breath of fresh air and gave those from outside B.C. a chance to see some stands and plantations for themselves. With the potential for growth modification seen at the thinning plots, the need for the breeders and managers to maintain close contact was emphasized.

The spouses and families joined the tour for lunch at the cookhouse and the C.T.I.A. owes a debt of gratitude to the Research Branch of the Ministry of Forests who provided an excellent meal for 200 people. Only the weather was a disappointment when, after a recent hot spell, it became cool and windy and only a few hardy souls stayed for a swim.

## PANEL DISCUSSIONS

SPRUCES

HARD PINES

WEST COAST SPECIES

## PANEL DISCUSSION

## SPRUCES

Chairman: J. Coles
Panel Members: A. Gordon, G. Kiss
Rapporteur: N. Dhir

Accomplishments and work in progress on genetics, genetic improvement and related research on major species of genus Picea across Canada was reviewed and discussed. Although most of the work has been concentrated on white spruce and black spruce; starting in recent years, more attention is being paid to sitka spruce, Englemann spruce, red spruce and interspecific hybridization among selected spruce species.

Starting in 1950's through the work pioneered by Petawawa Forest Experiment Station, a large number of provenance research plantations have been established throughout Canada. These experiments are yielding valuable information on geographic variability, species adaptation, seed source hardiness and superiority. Research results demonstrating growth superiority and broad environmental adaptation of Ottawa Valley white spruce provenances in much of eastern Canada is an excellent example of practical application of such work. Provenance trials of sitka spruce have more recently been established throughout coastal British Columbia.

Genetic improvement programs to develop superior strains of seed through selection and breeding for forest regeneration are active in white spruce, black spruce and Englemann spruce in several provinces. Interest and emphasis on applied breeding for genetic improvement of these species has picked up momentum in recent years. Older and well established spruce breeding programs are found in Quebec, Ontario and British Columbia. In recent years Alberta, Saskatchewan, Manitoba, New Brunswick and Nova Scotia have started genetic improvement programs in black spruce and/or white spruce. Several of these programs are currently spending great deal of effort and resources in examining alternate breeding strategies and developing comprehensive long range breeding plans.

Over the past many years, a large number of white spruce and black spruce progeny test plantations have been established throughout much of the country to provide information useful for applied breeding. Results from these studies are providing valuable information on genetic structure of populations, genotype x environment interactions, inheritance patterns and correlations among traits, and breeding value of parent genotypes.

Research on flowering and seed production in spruces has expanded considerably in recent years. Studies in progress in various regions consist of phenology of flowering, effect of different fertilizer treatments and plantation spacings on cone production, control of cone and seed insects and diseases, early induction of flowering using accelerated growth and gibberellic acid treatment, etc. Results from many of these studies have already contributed useful information for seed orchard programs.

In summary, research and genetic improvement programs in spruces are active in all provinces with varying level of emphasis. With the increasing level of interest and support for tree improvement generally evident throughout Canada, prospects for more concentrated efforts on developing necessary knowledge on genetics and silviculture of spruces, and its applications to increase yield and quality of future forests, are indeed very encouraging.

## PANEL DISCUSSION

## HARD PINES

Chairman: J. Klein
Panel Members: C. Ying, T. Rudolph, G. Buchert
Rapporteur: C. Hewson

### Lodgepole Pine Tree Selection

- In British Columbia insect and disease resistance is a primary consideration for selection. Also considered is stem and crown form and tree growth. Selected trees have approximately 10% height superiority over the stand mean. (C. Ying). A roadside selection program has been adopted. The age class distribution of the selected trees ranges from 65-145 years. This is very old but unfortunately younger stands seldom exist. (F. Yeh).

- In Alberta comparative measurements are made between selected trees and other dominants. Height superiority of the selected trees is between 12 and 17% (N. Dhir).

### Jack Pine Tree Selection

- In the Central Provinces a low intensity selection method has been adopted. Tree form and crown shape as well as size are used as selection criteria (J. Klein).

- In Ontario a large number (400-600) of plus trees are selected for a single breeding zone to allow for future roguing. Included in the selection criteria are stem straightness, branch angle, branch size and crown form as well as dominant height (G. Buchert).

- In New Brunswick 100-150 parent trees are selected annually. Their goal is to select 1000-1500 trees. Wood quality parameters (fiber length and specific gravity) are measured at DBH and half heights.

### Tree Improvement and Genetic Gain in Lodgepole Pine

- Establishing seedling seed orchards and roguing 75% of the families will result in a 15% genetic gain. A second generation clonal seed orchard will yield a 25% genetic gain. Standard error is about 30-40% of estimate for both programs (F. Yeh). In B.C. family information will be used to rogue first orchards (C. Ying). There is a trend

to reforest areas at closer spacing to reduce crown size. By improving crown form through breeding, planting densities could be reduced. (H. Goodman).

Tree Improvement and Genetic Gain in Jack Pine

- In Ontario seedling seed orchards will be rogued according to family performance and results from progeny tests (G. Buchert). In the prairie provinces genetic gain is an estimate based on the mean performance of the open pollinated progeny tests. Clonal seed orchards are not established until progeny information is available (J. Klein).

- There is an opportunity to turn over generations rapidly and within twenty five years we should have great confidence in our breeding program and should be establishing seed orchards through a breeding program rather than establishing orchards using original parent tree material (T. Rudolph).

Establishment of Family Tests

- In Alberta four tests consisting of 400 families have been established. Most technical and establishment problems can be overcome by ensuring that the field staff are well trained and understand the program. It is essential that close checks are maintained throughout all phases of the propagating and establishing stages of the program (N. Dhir and D. Young). Proper planning at the greenhouse stage eliminates many handling problems (J. Klein).

## PANEL DISCUSSION

## WEST COAST SPECIES

| | |
|---|---|
| Chairman: | O. Sziklai |
| Panel Members: | C. Heaman, M. Meagher, J. Maze, and special guest member, Alan Orr-Ewing |
| Rapporteur: | A. Fashler |

The discussion was opened by short statements from each panel member reviewing highlights of their individual member reports. J. Maze presented information on the patterns of variation and differentiation in several North American true fir (Abies) species. The current status of the British Columbia Ministry of Forests, western hemlock (Tsuga heterophylla) tree improvement program was summarized by M. Meagher. C. Heaman covered the progress in the breeding of Douglas-fir (Pseudotsuga menziesii) by the Ministry of Forests in coastal British Columbia.

Comments on the panel reports were made by Dr. Orr-Ewing. He stressed the need for continuity in forest genetics research, particularly in view of the long term nature of such activities.

The panel comments were closed by O. Sziklai with a very brief review of forest genetics and tree breeding at the Faculty of Forestry of the University of British Columbia.

Several questions were raised from the floor during the general discussion periods. The proportion of effort placed into selection was compared for Douglas-fir and western hemlock. Due to increased wages, intensive selection (1:5000) used for the early phase of Douglas-fir program was replaced by the lower initial selection intensity for the western hemlock program. Choice of the most appropriate selection intensity will depend on the number of trees being selected and on the silvical and genetic characteristics considered to be important. The ratio of effort placed on selection versus progeny testing was not available for the west coast species. However, the proportion of 1 to 4 selection to progeny testing was reported for northwestern Alberta.

The potential of vegetative propagation in western hemlock led to a discussion on the reliability and risk factors associated with early results from progeny testing. That is, although theoretically vegetative propagation can be utilized to establish clonal tests quickly and hence provide rapid generation turn-over and quick genetic gains, there is an associated risk with the reliability of results from young progeny tests. Reliability in early results can be increased

by increasing the number of test sites. Many workers reported that by about eight years data from progeny tests were stabilizing enough to make early selections, although a time interval of ten to fifteen years was considered safer.

The B.C. Ministry of Forests' reply to a floor comment questioning the loss of the Douglas-fir inbreeding program was that the Ministry is responding more directly to the needs of the Coastal Tree Improvement Council and that all programs cannot be continued due to changing priorities and a lack of sufficient resources.

The final topic discussed involved the field verification of realized gains for Douglas-fir. Emphasis had been placed in the past on deriving genetic information from progeny tests alone. The adequacy of the results was questioned and the discussion pointed to the need to establish field tests to obtain reliable information on realized genetic gain. However, this subject is now becoming important to the Technical Planning Committee of the Coastal Tree Improvement Council and field tests to estimate these figures will soon be established.

# MEMBERS' REPORTS

# CONTAINER SEED ORCHARD RESEARCH

C. Haeussler and S.D. Ross

B.C. Ministry of Forests
Research Branch
Victoria, British Columbia
V8Z 5J3

Key words: container seed orchards, flower stimulation, gibberellins, water stress.

A program of container seed orchard research was initiated in 1980 after a problem analysis by Ebell (1980) had indicated the great potential of this approach for accelerating the production of genetically improved seed. As envisaged, potted ramets would be cultured within an unheated polyethylene house the first 2-3 years for rapid vegetative growth; upon attaining adequate size flower stimulation treatments comprised of gibberellin (GAs) foliar sprays and induced water stress would be imposed on a biennial basis alternating with a year of cone maturation. In about 10 years when the ramets became too large for container culture, they would be outplanted to provide an immediately productive conventional seed orchard. This paper summarizes our progress to date (1980-81) and plans for future research.

## DEMONSTRATION ORCHARD

A 12.2 m x 15.2 m x 5.2 m tall polyethylene house was constructed at the North Road Laboratory in Saanich and a demonstration container seed orchard program established in early May, 1980. Western hemlock (Tsuga heterophylla (Raf. Sarg.) and white spruce (Picea glauca (Moench.) Voss) were chosen as major test species, the former because of its demonstrated responsiveness to hormonal flower stimulation (Ross et al. 1981), and the latter because of the great need for a consistant seed supply.

The potted 2- to 5-year-old western hemlock cuttings and 2- to 3-year-old white spruce grafts used were left-over production stock received only in late May and consequently left for treatment in the original containers and growing media. Western hemlock was represented by 1 to 15 ramets each of 34 clones (292 total). Half the ramets per clone received a slower stimulation treatment consisting of water stress and weekly foliar sprays of GA 4/7 (initially at 200 then 100 mg $L^{-1}$) beginning on 12 June and continuing 7 weeks for western hemlock and 12 weeks for white spruce. In the autumn, all ramets were repotted into 4.6 L or 9.2 L pots containing a hogfuel: sand (14.1) media with fertilizers preincorporated.

The stock used in this trial was of generally poor quality. This was especially true for the white spruce grafts which had just previously been transplanted from the orchard as vegetative buds were beginning to flush; the western hemlock cuttings had been grown continuously in pots and were severly rootbound. Under this weakened condition the treated ramets of both species suffered severely from the flower stimulation treatments (Table 1). An inability with the instrumentation at hand to adequately monitor and control plant water potential, together with excessive temperature build ups that from time to time exceeded 35°C within the polyethylene house, further compounded the problem. From previous studies (Ross et al. 1981) we know that the same GA 4/7 foliar spray is only very slightly phytotoxic when applied to healthy western hemlock.

The surviving western hemlock cuttings, however, flowered profusely in response to GA 4/7 + water stress treatment (Table 1). Treated ramets averaged 175 pollen cones and 32 seed cones each, as compared to 2 and 0.5 each, respectively, for controls. Eighty-eight percent of the ramets representing 100% of the clones produced pollen cones, and the respective percentages for female flowering (79% and 97%) were similarly high. Although other studies had shown that exogenously applied GA 4/7 will induce precocious female flowering, the level of male flowering far exceeded anything previously observed for field-grown or potted stock cultured outdoors (Ross et al. 1981, Brix and Portlock, in prep.). The work of Pollard (in prep.) indicates that this may be related to the severe water stress and high air temperatures experienced by the potted cuttings within the polyethylene house. There are also indications from studies on other species that the polyethylene-house environment is preferentially beneficial for male flowering (Brondbo 1969, Tompsett 1978, Luukkanen 1980; Ross unpublished results).

Despite the severe defoliation and shoot dieback, the induced seed cones are developing normally; they will be harvested in the fall for determination of total and filled seed. Copious quantities of pollen were shed, samples of which were collected for viability testing.

In contrast to western hemlock, only a few white spruce grafts flowered with or without GA 4/7 + water stress treatment (Table 1). Although spruce as a genus is more recalcitrant than western hemlock, the polyethylene-house environment and GA 4/7 applications have been particularly effective in promoting flowering in Sitka and Norway spruce (Tompsett 1978, Luukkanen 1980). There are probably several reasons why the treatment was ineffectual in the present trial. Firstly, treatment was apparently initiated too late in the season to influence cone-bud differentiation. Secondly, white spruce may be similar to Douglas fir (Ross, unpublished results) in that GA 4/7 is only marginally effective when applied as an aqueous foliar spray versus direct injection into the phloem and xylem as in the other studies on spruce. Finally, the problem of over stressing of recently transplanted stock has already been discussed.

Table 1. Flowering and growth response by potted western hemlock cuttings and white spruce grafts within a polyethylene house to gibberellin (GA 4/7) and water stress (WS) treatment.

| Treatment Response | western hemlock | | white spruce | |
|---|---|---|---|---|
| | Untreated controls | GA 4/7 + WS treated | Untreated controls | GA4/7 + WS treated |
| **Growth** | | | | |
| Ramet mortality (%) | 5 | 32***[3] | 0 | 4 |
| Leader dieback (%)[1] | 0 | 20*** | 2 | 22 |
| Defoliation (%)[1] | 1 | 26*** | 11 | 42 |
| Shoot Elongation (mm)[2] | 299 | 195*** | 130 | 127 |
| **Female Flowering**[1] | | | | |
| Seed cones/ramet (no.) | 0.5 | 32*** | 0.2 | 0.5 |
| Ramets flowering (%) | 3 | 79*** | 2 | 3 |
| Clones flowering (%) | 10 | 97** | 3 | 11 |
| **Male Flowering** | | | | |
| Pollen cones/ramet (no.) | 2 | 175*** | <0.1 | <0.1 |
| Ramets flowering (%) | 10 | 88*** | 1 | 1 |
| Clones flowering (%) | 24 | 100** | 3 | 4 |

[1] Based on surviving ramets

[2] Based on undamaged ramets

[3] Treatment effect significant at $P \leq 0.01$ (**) and $P \leq 0.001$ (***) based on paired t-test of ramets within clones.

## RESEARCH PROGRAM

Research in support of the container seed orchard program was intensified in 1981. A new tree physiologist was hired. Up to 200 ramets each of good female and/or male flowering plus-tree clones of western hemlock (11 clones) and white spruce (20 clones) were propagated and will provide abundant high quality experimental material for research beginning in 1982. There are also plans to triple the existing area of polyethylene houses.

In priorizing research needs, the strategy was adopted that we first need to better define the biological requirements for early and continued abundant seed production, and then develop more cost-effective cultural and treatment regimes for operational use.

Studies initiated in 1981 had the following objectives:

1. Delineate the critical period(s) for influencing seed-, and pollen-cone differentiation in white spruce;

2. Determine the optimum timing and duration of water stressing used in conjunction with GAs;

3. Test hypothesis that the polyethylene-house is environmentally beneficial to male flowering, whereas female flowering is better outdoors; and

4. Determine optimum media and container sizes for the initial growth-acceleration phase of ramet culture.

Research was also initiated, using Douglas fir as the test species, to develop improved GA formulations and more cost-effective methods for their application. In the application of pesticides, improved target coverage has been achieved with greatly reduced quantities of expensive chemicals using ultra low volume (ULV) spray equipment; pesticidal activity is further enhanced if oil-base instead of aqueous formulations are used. Preliminary assessment of ULV sprays of aqueous and anti-evaporant oil formulations of GA 4/7 is presently underway, with further testing of additional oils scheduled for 1981. Also being evaluated at the suggestion of Dr. R.P. Pharis (Univ. of Calgary) is a dimethyl derivative of GA 4 which, in the dwarf-corn bioassay system, has been found to be up to 10 times more effective than the GA 4 free acid we are presently using.

Because of their ability to flower profusely at a very young age in response to GA 3, yellow cedar (Chamaecyparis nootkatensis (D. Don) Spach) and western red cedar (Thuja placata Donn) are ideal candidates for the container seed orchard. Up to 6 additional ramets of each clone in yellow cedar orchard No. 37 and red cedar orchard No. 39 were propagated in 1981 and will be used to establish a direct comparison of outdoor and polyethylene-housed container orchards with soil-based seed orchards. A separate study was initiated in 1981, using field-grown seedlings and

cuttings, to determine the optimum timing, duration and frequency of GA 3 applications for promotion of female and male flowering in these species.

Additional key needs that future research will address include: better methods for monitoring and controlling water stress, improved horticultural regimes for growth, flower stimulation and cone maturation; and crown-training regimes that will extend the time that stock can be practically managed for cone production in pots, and that will also increase the proportion of shoots with high potentials for differentiating seed and pollen cones.

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# A BREEDING PROGRAM IN COASTAL DOUGLAS FIR (P. MENZIESII MIRB. (FRANCO)) 1979-1981

J.C. Heaman

*Ministry of Forests*
*Research Branch*
*Victoria, British Columbia*
*V8W 3E7*

Key words: Douglas fir, recurrent selection, progeny testing, diallels.

Tree improvement work in coastal Douglas fir has been taking place since 1957 with early emphasis on selection and seed orchard establishment. Emphasis is now placed on a breeding program where controlled-pollinated progeny of the original plus tree selections are being established in field trials. Selections will be made in the pedigreed F1 material for the second generation of seed orchards and information will be generated to guide breeding approaches and to permit some culling of the first seed production orchards. Since 1975, eleven new test sites have been planted annually, bringing the current total to 66. Some preliminary measurements have been made but the present work still is devoted largely towards crossing and establishing the plantations.

## BACKGROUND

Plus tree selection in a program for improvement in coastal Douglas fir was started for the British Columbia Forest Service in 1957 by Dr. Alan Orr-Ewing and, aided by the forest companies and by the University of British Columbia, was continued actively until 1966. By that time a workable breeding population had been assembled and priorities for the limited funds had to be directed toward test plantation establishment and maintenance.

Selection has continued to fill gaps in the initial coverage and as the provenance plantations provide more reliable information, this population is being refined.

The selected trees were grafted for use in the first level seed orchards. They were also established in a clone bank at Cowichan Lake Research Station. This serves as an archive for the artificial preservation of a gene pool and as a breeding arboretum. As cones and pollen have been produced there and in the seed orchards, a breeding program has been developed.

Although the background of the breeding program has been given in previous biennial reports, an outline is repeated here so that the current work can be seen in perspective.

## RECURRENT SELECTION PROGRAM

First priority has been given to a recurrent selection program in a population of selected trees from Coastal British Columbia and Northern Washington. Eventually about 350 trees will be involved and the project is designed to provide material and information from which future, reconstituted seed orchards may be developed. Its chief impact will be on the lower to middle elevation zones, 0-600 m.

The objectives are:

(a) the production of progenies by crossing between selected plus trees and their establishment in test plantations for second generation selection,

(b) the estimation of genetic parameters to guide future breeding decisions,

(c) The study of the occurrence and importance of genotype-by-environment interactions so that the populations may be grouped effectively,

(d) The testing of the parents to permit some culling of the first seed orchards through a ranking of general combining ability.

Although reciprocal effects are being ignored at present, some information will be generated on reciprocal effects by the inclusion of reciprocal combinations where available.

A disconnected, modified diallel mating design is being used and five crosses per parent are expected to provide adequate information and yet represent a feasible project. Each cross is represented in the field tests by almost 200 seedlings, and the sites are being distributed to sample the range of coastal environments from 0-600 m elevation.

Each modified diallel comprises six parent trees taken, theoretically, at random from the total population. The allocation of parents as male or female components in the diallel depends on the available numbers of reproductive buds. Thus, a completed modified diallel contains 15 crosses. Groups of 5-10 of these diallels are being planted annually, but 10 percent of the crosses are sown in the following year to provide a bridge between years of planting.

Crossing for this program was started in 1974, with the first plantations planted in fall, 1975. The project has continued to expand annually as suitable clones came into flower production. One of the advantages of the disconnected modified diallel is that failure of crosses will affect only that individual unit, and balanced planting designs can be stipulated. Incomplete groups can be held and completed in another year.

The stock is grown as long-season, styro-8 plugs. These are sown in the greenhouse in early spring, ready for planting in the fall or

following spring. The field design comprises four replications of four-tree row plots. All crosses are planted on the eleven test sites, which are widely distributed to provide information on genotype-by-environment interactions. The test sites are selected from the available logging and rehabilitation sites. The most important criteria are homogeneity and distribution with respect to biogeoclimatic subzones where Douglas fir is the prime species.

As with any single breeding approach, the diallel project has both strong and weak features but it does meet the stated objectives of providing in a single program both information and material for future breeding.

By using full-sib families, the breeder can control the levels of inbreeding within the successive breeding and seed-producing populations. Levels of inbreeding in the initial population are not known but can be examined using isoenzyme techniques, but subsequent changes can be controlled by the breeder. The disconnected modified diallel groupings have the advantage of permitting the accumulation of balanced entries for field testing.

On the other hand, the scale of the project, in which five crosses must be made and planted to evaluate each parent, and the reduced precision of estimating general combining ability by the diallel groupings, can be seen as weaknesses. These will be most important if parental evaluation and orchard culling are given high priority, but under the present British Columbia situation, with mixed wind-pollinated seedling and clonal orchards, the priority has to be given to selection of new material for the replacement orchards. Lack of uniformity of sites which reach almost 3.5 hectares, relatively small numbers of seedlings per family on any site and the confounding of sites and years are related to the scale of the program and represent possible, but acknowledged, weaknesses.

The strength of the program lies in there now being over 200,000 seedlings of known parental origin scattered widely across the coastal area. These progenies result from rigid mating and planting designs and precise information on the population will soon be available.

From this brief outline it will be seen that this is an extensive program and that during the early stages major efforts have to be devoted to producing the cross-pollinated families and establishing the test sites. Achievement is measured in terms of area planted, parent trees brought into the testing program and crosses made. Weeding and general site maintenance are essential and with 77 test sites already in the field, this function assumes major proportions.

Two more seasons of controlled pollination have been carried out since the last report and this has brought a total of 312 parents into the plantation phases. A total of 66 test sites, each of about 3.5 ha, have been planted. A further 11 sites are being laid out currently to receive the stock now growing at the Cowichan Lake Research Station. As the

provisional objective of 350 parent trees within the program is approached, fewer parents are available for crossing each year and with a poor crop year in 1980, a small expansion of this program resulted. Progress to date is summarised in Table 1.

Table 1 Progress in E.P. 708 - A Breeding Program in Coastal Douglas fir

| Series | Sowing Year | Parents | Modified Diallel groups | Crosses Planted * | Test Sites |
|---|---|---|---|---|---|
| I | 1975 | 60 | 10 | 177 | 11 |
| II | 1976 | 30 | 5 | 99 | 11 |
| III | 1977 | 54 | 9 | 165 | 11 |
| IV | 1978 | 54 | 9 | 170 | 11 |
| V | 1979 | 48 | 8 | 153 | 11 |
| VI | 1980 | 48 | 8 | 140 | 11 |
| VII | 1981 *** | 18 | 3 | 55 | 11 |
| TOTALS | | 312 | 52 | 959 | 77 |

* Includes 10% overlap crosses and reciprocal samples.
*** Crosses now in greenhouse at Cowichan for planting 1981-82.

To permit interpretation of GE effects, a start was made in 1980 to collect ecological information on the test sites. Most of the work to date has been based on mapping undisturbed land before logging, but the examination of the test sites will include samples from disturbed sites also. The work of the first year was largely exploratory and seventeen sites were examined. A report is being prepared.

The moist summer of 1980 gave exceptionally good survival and growth but browsing by grouse, deer, rabbits and stem chewing by voles still present serious problems. Fencing would bring only partial protection and some trials using open-ended milk cartons to protect terminal buds and current growth are showing promise.

With such a long term project there is a tendency to measure the plots as soon as they are established but while general inferences may be possible, no action can be taken on the data and it will not be until the 10-year data are collected that useful interpretation can be expected. If priorities permit, measurements will be taken in the fifth or sixth years after planting to provide preliminary information.

Maintenance and measurements have been continued on the wide interracial crosses planted by Dr. Orr-Ewing but generalizations are not easy. It is clear, however, that crosses between parents from coastal British Columbia and those from coastal locations in Washington, Oregon and California can produce vigorous stock for B.C. coastal conditions. These plantations also present a means of investigating juvenile-mature correlations.

# TREE BREEDING AND ASSOCIATED RESEARCH, BRITISH COLUMBIA MINISTRY OF FORESTS, 1979-1981

K. Illingworth

*Ministry of Forests*
*Research Branch*
*Victoria, British Columbia*
*V8W 3E7*

Key words: tree improvement cooperatives, tree breeding, provenance, propagation, seed orchards.

## TREE IMPROVEMENT ROLES WITHIN THE MINISTRY OF FORESTS

The genetic improvement of forests can be considered in two main phases: (1) the scientific production and testing of genetically-improved breeds; (2) the mass replication of tested breeds in production seed orchards on a scale commensurate with operational goals. British Columbia is unusual inasmuch as the responsibility for these two phases resides, largely through historical development than design, in sections of two different branches of the Ministry of Forests viz., the Research and the Silviculture Branches respectively. Each phase has its own Program Manager and budget, although integration is achieved through daily working contacts, as well as through more formal means such as technical committees, councils, etc. This report is concerned primarily with summarizing recent developments affecting tree improvement in British Columbia and, particularly, progress within the Tree Improvement Section of the Research Branch.

## ENABLING LEGISLATION AND THE DEVELOPMENT OF COOPERATIVES

During the period 1979-81, British Columbia witnessed developments of major consequence for tree improvement, seed orchards and associated research. These were enabled by Provincial legislation, the Forest Act (1978) which, among many innovations, fosters a cooperative Ministry/Industry approach to solving timber supply problems. In particular, it provides for funding through credits against stumpage, and cut-incentives for intensive forestry programs developed within the context of a rolling Five Year Forest and Range Program plan. Tree improvement cooperatives, incorporating senior personnel from the Ministry and major licencees, have been formed; the Coast Tree Improvement Council (C.T.I.C.) in 1979 (M. Crown 1979); the Interior Tree Improvement Council (I.T.I.C.) in 1981. Working through technical planning committees, comprising tree breeders and forest managers from all sectors, these councils have provisionally identified a need for a total of 316 ha of cooperatively-managed seed orchards of ten coniferous species. The orchards are to yield sufficient seed for the nursery

production of 120 million seedlings annually by 1994. Genetic improvement is an integral part of the overall program. It is against this background that the following enumeration of program highlights, services and resources is presented. Reports detailing individual programs have also been prepared for these proceedings by J.C. Heaman, I. Karlsson, G. Kiss, M. Meagher, C. Ying and J.E. Webber.

## PROGRAMS

Components of the role assigned to the Tree Improvement Section include:

1. Producing and testing genetically-improved breeds of those species named in the cooperative programs; estimating genetically-based increases in wood yields to guide future breeding strategies and to provide a basis for the allocation of cut-incentives to industrial cooperators in the program;
2. Conducting research on problems associated with seed orchards, breed production and the genetics of species in the program;
3. Propagation for all breeding arboreta, coastal seed orchards and clone banks;
4. Establishing and maintaining master clone banks and gene archives;
5. Establishing work criteria, monitoring and adjudicating cost claims from the private sector for tree-improvement work done on approved programs;
6. Developing and maintaining research stations at Cowichan, Vernon, Red Rock and Saanich to facilitate the above and other forest research, meetings, training sessions and public information.

In responding to this mandate, highlights of the past two years are:

1. Completion of the Vernon Research Station and Seed Orchard facility, comprising offices, physiology labs, pollen extraction and cold-storage facilities, greenhouses, lathhouse and service areas located on some 60 ha; Vernon is to be the centre for tree improvement, seed orchard management and associated research in the southern Interior;
2. Completion of a propagation facility at Cowichan Lake, comprising five large greenhouses, rooting house and service buildings; expansion of adjacent nursery and clone bank areas;
3. Production at Cowichan, in the first year of operation, of 33,000 grafts and 60,000 rooted cuttings, with 100,000 rootstock under cultivation for future needs;
4. Completion of planned matings and planting in the coastal Douglas fir recurrent selection program, bringing to 66 the total number of 3.5 ha progeny tests now established; planting of two series of o.p. progeny tests of western hemlock at eight locations each;

continuation of parent tree selection and propagation in hemlock, true firs, lodgepole pine, Sitka and the interior spruces;

5. Maintenance and assessment of all progeny tests, as scheduled, and identification of clones for the constitution of three 1½-generation orchards of interior spruce. Completion of selection and propagation for the establishment of four first-generation orchards of lodgepole pine;

6. Maintenance and scheduled assessment of provenance experiments with Sitka spruce, white spruce, Douglas fir and lodgepole pine; establishment of new trials with amabilis fir and grand fir at six locations; preparation of ten test sites to receive noble fir trials in autumn, 1981. The assessment of 780 wind-pollinated families of lodgepole pine is providing indications of genetically-based susceptibility to gall and stem rusts and terminal weevil in that species.

   It is pertinent to record that the total area under arboreta, progeny and provenance tests now totals some 775 ha containing more that 800,000 trees;

7. Clearing, cultivation, fencing and establishment of master clone banks continued at Cowichan Lake, Vancouver Island, and Barnes Creek, some 60 km from Vernon;

8. Participation by tree improvement staff in the development of cooperatives - including such activities as definition of work criteria for cost claims; participation in seed orchard managememt committees; training workshops for parent-tree selection, scion collection and propagation;

9. Technical advice and participation by tree improvement staff in a 27 minute film on tree improvement.

## STAFF

Staff, including the Program Manager and Technical Advisor, Dr. Francis Yeh, now totals 8 professionals. The provenance program, for two years somewhat neglected through transfer of the writer to the role of Program Manager, was recently taken over by Dr. Cheng Ying, in turn vacating the position of lodgepole pine breeder - as yet unfilled. Barry Jaquish came to the Section recently from the University of Alberta. He will work with Gyula Kiss at Vernon, specifically addressing himself to progeny testing in white and Engelmann spruce.

In addition, physiological research on flower induction and enhancement, accelerated growth, pollen processing and management and other topics in support of the overall program is being conducted by staff of the Branch's Tree Physiology Section, notably Dr. Joe Webber, now joined by Dr. Steve Ross who was, until recently, with Weyerhaeuser Co. at Centralia, Washington.

During the past six months all breeding programs benefitted enormously from the critical guidance of Dr. C.J.A. Shelbourne, on leave

of absence from the Forest Research Institute, Rotorua, New Zealand. Tony's assignment included a review of the entire breeding and genetics program, especially in coastal Douglas fir, and its interaction with the seed orchard program. The coastal programs are also under review by a technical subcommittee (of the C.T.I.C.) on breeding strategies, a group comprising tree geneticists and breeders from all sectors - public, private and academic (U.B.C.).

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# COWICHAN LAKE RESEARCH STATION, B.C.
# 1979-1981

Ingemar Karlsson

*Ministry of Forests*
*Research Branch*
*Mesachie Lake, British Columbia*
*V0R 2N0*

Key words: supplemental pollination, compatible rootstock, rooted cuttings.

Research projects at the Station include supplemental pollination in the Douglas fir clonebanks; development of compatible rootstocks in Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) and rooting of cuttings in yellow cedar (Chamaecyparis nootkatensis (D. Don) Spach).

## SUPPLEMENTAL POLLINATION IN DOUGLAS FIR (E.P. 780-07)

In the spring of 1980, a study to determine the effects of supplemental pollination ("boosting") in Douglas fir was carried out on 20 trees in a 15 year old plantation at Cowichan Lake Research Station. Earlier experiments suggested that supplemental pollination could reduce seed yield by increasing cone abortion. This effect was greatest if pollination was carried out in cloudy or wet weather.

Flower development was monitored closely and weather conditions recorded. It was planned to restrict pollen application as far as possible to extreme weather conditions, both wet and dry. However, since there were insufficient rainy days during the pollination period, some trees were boosted in early morning while the relative humidity was still high.

Unfortunately, a heavy infestation of cone insects made meaningful seed counts for the different treatments impossible. However, Table 1 shows the mean percentage figures for frequencies of cone abortion for the two relative humidity groups.

Table 1. Effect of Relative Humidity on Cone Abortion (percent)

| | Relative Humidity at time of boosting | |
|---|---|---|
| | 20-50% | 50-100% |
| Boosted | 8 | 38 |
| Control | 8 | 21 |

There is a close relationship between relative humidity at the time of boosting and cone abortion. This was even more pronounced when it was raining at the time of application.

Generally, it appears that to minimize cone abortion, supplemental pollination should be done only during dry and warm conditions and should not start until the relative humidity is below 50%

## COMPATIBILITY TESTING OF DOULGAS FIR ROOTSTOCKS (E.P. 648.02)

Rootstock of 42 different origins, mostly from crosses between clones showing high graft compatibility, were grafted in 1979 with tester clones. These graft unions were cut off in February 1981 and are now being sectioned and assessed for compatibility using the micro-technique method (Copes 1967).

The results from this screening technique will be integrated with observations of transplanting shock, flushing time, vigor, and height growth of the scions during the first two growing seasons, to identify the best crosses for use as rootstocks for production grafting.

Seedlings from the same 42 families were planted in the field in 1979 for long term observation. These seedlings were grafted in March 1981. This study will compare the early tests for delayed incompatibility with later field performance. Also, it will provide guidance for selection of parents for rootstock production and provide material for establishing selected rootstock genotypes by rooted cuttings.

## EFFECT OF UNDERSTOCK ON VIGOR AND CONE PRODUCTION IN GRAFTED DOUGLAS FIR (E.P. 648.10)

In 1978, controlled crosses were made in a complete diallel design, omitting selfs, between six Douglas fir clones of high graft compatibility. The objectives of this study are:

(a) to gain information on the influence of rootstock vigor on graft compatibility and on growth performance of the grafts, and
(b) to determine if flowering patterns of the rootstocks influence the flowering of the grafts.

Twenty seedlings from each of the 30 cross combinations were planted on a field site at Skutz Falls, near Lake Cowichan in the fall of 1980. These crosses will be assessed for growth and flower production.

Another 25 seedlings from each cross were potted and grafted in the greenhouse in March 1981. Five plus tree clones: 2 "heavy" cone producers, 1 "intermediate" cone producer and 2 "non-producers", are being used as testers. These grafts will be planted in the field after two years and differences in compatibility, growth rate and cone production will be studied.

## HEDGING ORCHARD OF YELLOW CEDAR (E.P. 750.03)

The hedged bank of yellow cedar from a variety of high elevation sources, which was established at the Cowichan Lake Research Station to provide material for the large scale production of rooted cuttings, was described in the previous report. The seedlings, which are planted in rows 3.75 m apart, 90 cm between seedlings, have now reached productive size.

Practical trials in 1980 with a few thousand cuttings using Spencer-Lemaire containers rooted with over 80% success. The use of Spencer-Lemaire containers has the advantage that the cuttings can be planted directly from the container to the field, without unnecessary disturbance of the delicate root systems.

Following this success, some 75,000 cuttings were clipped from the hedging orchard in January 1981 and set in Spencer-Lemaire containers in greenhouses. The resulting stock will be planted under production conditions in fall 1981. In some of these plantations family identity will be maintained and survival and growth plots established.

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# GENETIC IMPROVEMENT OF WHITE AND ENGELMANN SPRUCE IN BRITISH COLUMBIA 1979-1981

Gyula Kiss

*Ministry of Forests*
*Research Branch*
*Victoria, British Columbia*
*V8W 3E7*

Key words: white spruce, Engelmann spruce, tree improvement, progeny trials, tree breeding, hybridization.

The objective of this project is to produce genetically-improved seed of white and Engelmann spruce (Picea glauca (Moench) Voss, P. engelmannii Parry).

The following progress has been made in the program since my last report (Kiss 1978a):

## OPEN-POLLINATED PROGENY TRIALS

Six-year (9 years from seed) height measurements were carried out at all the open-pollinated progeny test sites. Analysis of the data indicated that a gain of 10-15% in height growth can be attained by establishing the top 25% of the original parents in clonal seed orchards. While 6-year results are by no means conclusive, they will be used as guidelines in establishing "one-and-a-half" generation orchards. By the time these orchards reach production age (estimated 10-15 years) further data from the progeny tests should permit more reliable estimates of gain and provide a basis for more rigorous culling.

The data also indicate that the more-vigorous families survive better than slower-growing ones, a difference which is especially striking in the presence of competing vegetation.

Another result, not directly related to tree breeding, was that progenies survived, grew and expressed differences better on well-prepared sites than on poorly-prepared ones. For example, in 1978, the average seedling height at the well-prepared Red Rock plantation (Kiss 1975) was 104.6 cm, while the average height at the unprepared Quesnel site was 72.9 cm. This represented over 43% difference in height growth alone. Survival was 98% at Red Rock and only 86% at Quesnel. Similar results are found on test sites of other selection units.

## BREEDING ARBORETUM

The Vernon Breeding Arboretum (Kiss 1978 b) is near completion. Strobili production on established ramets increased steadily (Kiss 1977b, 1978b, 1979) until 1981 when production suffered a drop. Probably, this could be attributed to the cold, wet summer in 1980, coupled with heavy irrigation. This year we intend to stress some ramets by reducing irrigation, the objective being to increase strobili yield in 1982.

The drip irrigation used at Vernon utilizes treated municipal effluent. It has been applied for the last two summers without deleterious effects.

The Trinity Creek Breeding Arboretum (Kiss 1978a) had to be abandoned due to drought problems resulting from low precipitation and shallow soil. It has been replaced by a new clone bank at Barnes Creek, 60 km north-east of Vernon.

## NOTES OF INTEREST

### Grafting

To establish a Picetum at the Vernon site, various species of Picea have been grafted onto British Columbia white spruce rootstock. To date, little incompatibility has been found. For further information, contact this writer.

### Albinism

To date, three of the 181 selected trees from the Prince George selection unit have been identified as carriers of albino genes. This trait appears to be controlled by a single gene with at least two alleles. One of the alleles is recessive and undetectable in heterozygous condition. The other allele appears more like a co-dominant as it can be identified in the heterozygous condition by examining the needles. The tips of the needles, when exposed to direct sunlight, turn golden yellow. This gives the appearance of a "golden-hue" to the branches. Both alleles are lethal in the homozygous condition.

The trait deserves further investigation as two of the carriers are included in the open-pollinated progeny trials and score high in overall ranking (5th and 48th out of 174).

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# THE ROLE AND ACCOMPLISHMENTS OF THE SILVICULTURE BRANCH B.C. MINISTRY OF FORESTS, IN COOPERATIVE TREE IMPROVEMENT, 1979-1981

J. Konishi, M. Crown, M. Albricht, C. Hewson and C. Bartram

*Silviculture Branch*
*B.C. Ministry of Forests*
*1450 Government St.*
*Victoria, B.C.*
*V8W 3E7*

Key Words: tree improvement cooperatives, seed orchards, root pruning, booster pollination, propagation.

Cooperative tree improvement in B.C. is a recent development involving the Ministry of Forests and numerous forest companies. A coastal cooperative has been active since 1979, an interior cooperative is currently being established. The workload is shared and costs incurred by the companies are re-imbursed through credit to stumpage accounts as per Section 88 of the Forest Act. This paper describes the role of the Silviculture Branch in these cooperatives and reviews recent Branch accomplishments, both collectively and by three administrative regions.

## STRUCTURE AND ROLE OF THE SILVICULTURE BRANCH, MINISTRY OF FORESTS

Each cooperative is headed by a Council, consisting of upper management staff, which is responsible for making recommendations to the provincial Chief Forester regarding program objectives, strategies, agency involvement, allocation of workload and research needs. At the planning level Technical Planning Committees (TPC's) review seed orchard working plans and other associated tree improvement projects and input technically to the Councils. One committee now exists for the Coast; two will be formed in the interior (a southern and central TPC). A coordinator is assigned to each TPC and is primarily responsible for the administration of projects, review of the technical aspects of the program and the adjudication of industrial cost claims. Coordinators also serve as secretaries to Council.

The Silviculture Branch plays an active role within this structure. Administratively, the Branch Director and Manager of the Seed Production sit on both Councils. The coordinator positions are filled by Branch personnel. The Branch is also responsible for the management of all cooperative orchards assigned to the Ministry. Three project foresters provide technical direction, conduct trials, prepare orchard working plans and develop orchard management prescriptions. Technical staff provide direct supervision of orchard management operations and manage specific orchards. A planning officer and orchard pest management officer complete the staffing picture. In all, nine

professional and eight technical positions within the Branch participate directly in cooperative tree improvement.

## ACCOMPLISHMENTS

Several accomplishments involving group staff efforts can be highlighted. These include:

1. Formulation of an interim Seed Orchard Planning Zone Map based on input from ecologists and forest geneticists (Figure 1);
2. Preliminary planning for the interior cooperative program - review of species needs and priorities, identification of seed orchard opportunities and estimation of funding requirements;
3. Input into a recently completed tree improvement film entitled, "Seeds For Tomorrow";
4. Input into a technical audit entitled, "Review of Practises Relating to the Treatment of Seed Orchard Seed and Seedlings";
5. Completion of a parent tree selection guideline and revision of the field form to reflect cooperative needs;
6. Revision of ramet/seedling seed yield data for seed orchard planning.

## COAST HIGHLIGHTS

The Silviculture Branch is presently responsible for the management of four Douglas-fir orchards covering 23.6 ha on the coast. Management highlights include:

1. The harvest of 81.6 and 14.3 kg of seed in 1979 and 1980 respectively (sufficient for 7.25 million plantable seedlings);
2. The successful induction of early and profuse flowering through root pruning;
3. The control of seed insects with the insecticide dimethoate;
4. The operational application of booster pollen by hand and helicopter;
5. The collection of baseline soil moisture and nutrient data to aid future management.

Several trials were implemented to promote better orchard management. These include screening of various insecticides, evaluations of short and long term effects of root pruning, and studies of flower abortion rates. Further orchard management studies in nutrient status, soil moisture, cone induction, pollination and insect control are currently being developed.

Individual orchards were also expanded or reconstituted as per TPC recommendations. Site preparation work continued for an additional 25.4 ha of new cooperative orchards to be managed by the Ministry.

Administratively, the development of cooperative procedures and policies is noteworthy. An annual events schedule, breeding strategy review sub-committee, standards and procedures of work performance, detailed financial arrangements and composite working plan formats are now in place.

## SOUTHERN INTERIOR HIGHLIGHTS

The purchase of 60 ha near Vernon in 1979 marked an important step for the southern interior orchard program. This property has subsequently been site prepared and fenced and will, along with the Skimikin Forest Reserve (near Salmon Arm), contain all cooperative orchards managed by the Ministry in this region.

Orchard establishment operations, initiated in 1979, progressed quickly. Six young interior spruce orchards totalling 17.6 ha have been planted at Skimikin. A small western white pine seed production plantation was also established from a genetically rust resistant strain obtained from the USDA, Idaho. At Vernon, two interior spruce orchards totalling 4.2 ha were recently planted. A total of 16 orchards spanning 51 ha are planned for establishment on these two sites. Interior spruce will form the main species component.

Management within these young orchards consisted primarily of additional cultivation, establishment of cover crops and growing stock maintenance (pruning, weeding, fertilizing). Trickle irrigation systems were also installed. A small seed crop totalling 90 g was harvested in 1980 from four of the orchards at Skimikin.

Several trials have been implemented and include:

1. A preliminary evaluation of booster pollination and monitoring of foreign pollen;
2. A comparison of various weed control methods - herbicides, mulches, manual;
3. Monitoring and control of spruce cone rust and insects;
4. Determination of the effects of fertilizers on stock vigour and flowering;
5. Studies of the effects of Accelerated Optimum Growth, root pruning, and ramet spacing on flowering.

In addition a detailed soil survey has been completed at Skimikin, the results of which have been included in draft orchard working plans.

Parent tree selection/collection activities also comprised an important portion of the work. To date over 1300 interior spruce have been selected in the southern interior. In anticipation of an expanded selection effort, two workshops were conducted to review procedures. A commensurate grafting program of approximately 12,000 grafts/year continued at Skimikin.

## CENTRAL INTERIOR HIGHLIGHTS

Seed orchard activities in the central interior are presently confined to the Red Rock Forest Reserve (near Prince George). The Silviculture Branch manages four lodgepole pine orchards spanning 14.8 ha, the most recent of which was established in 1979, and maintains

over 75 ha of tree improvement plantations. Recent planning indicates that all pine orchards will require expansion to meet seed needs.

Highlights include orchard working plan preparation, additional site cultivation, establishment of cover crops and application of 28 litres of booster pollen (collected over the past two years from natural stands and an adjacent provenance trial). Soil and nutrient analyses were also completed. A fertilizer trial in one orchard demonstrated increased tree vigour, cone size, seed production and seed viability. The significant incidence of insect and disease problems, especially in lodgepole pine, also prompted intensified pest monitoring and control actions.

To date over 1500 interior spruce parent trees have been selected in the central interior. A collectable cone crop in 1979 enabled the harvest of open-pollinated seed from over 900 parent trees for progeny testing. Helicopters have been used extensively for this work and a safety plan to help ensure safe work practises was accepted by the Workers' Compensation Board.

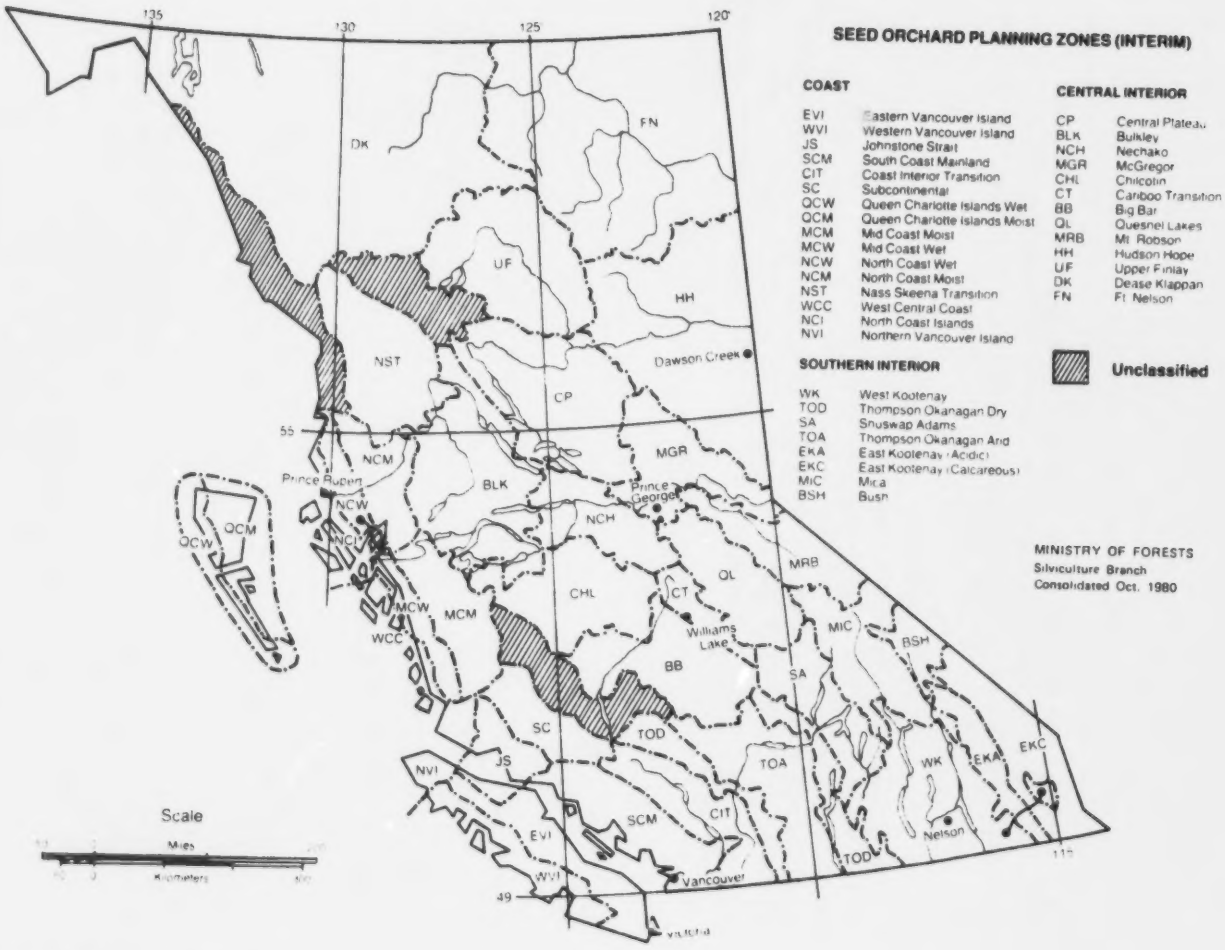


Figure 1. Seed orchard planning zones (interior).

# WESTERN HEMLOCK TREE IMPROVEMENT FOR COASTAL BRITISH COLUMBIA 1979-1981

M. Meagher

*Ministry of Forests*
*Research Branch*
*Victoria, British Columbia*
*V8W 3E7*

Key words: Tsuga heterophylla, tree selection, progeny testing, provenance testing, breeding.

The program began April 1, 1977. It entails screening of many parent (plus) trees per seed zone for GCA via open-pollinated progeny tests. Population studies may supplement those tests to define seed zones better and increase breeding options. A number of support studies are planned or underway to develop techniques and to assist in interpretation and application of results when the progeny tests are evaluated, perhaps at 15 years.

Tree selection, seed and scion collection have all continued and accelerated due to the commencement of the B.C. Government - Industry Cooperative tree-improvement program (Crown, 1980). To date, 1078 trees, including 26 obtained from U.S. cooperators, have been selected. Most are propagated clonally by grafting or rooting, or both, for seed orchards and clone banks. All trees were selected to targets set by arbitrary seed-orchard planning zones and elevation bands. Most selections were made from the ground, but some inaccessible areas were sampled from a helicopter. A good 1979 seed crop yielded 162 useable seed collections; no crop developed in 1980, but prospects for 1981 appear favourable.

A second series of open-pollinated progeny tests was established for the West Vancouver Island Zone (Seed Zone 1010) and the third has been sown to test trees from the Johnstone Straits zone (Seed Zones 1020 north and 1040 north). Survival of the first test series averaged 88%, and ranged from 78% to 98% after 1 year in the field.

Data from the Canadian Forestry Service population test and from progeny tests established by Tahsis Co. were useful in drawing up clonal lists for 3 of the 7 seed orchards approved by the Tree-Improvement Cooperative. All seed orchard clonal lists were checked to determine suitability to the Co-op standards, and revised where necessary.

Support studies continued, with expansion to a complete 13-parent diallel among convenient study trees being attempted. Pollen has been collected from the disjunct, "Interior" portion of the species' range, and some has been received from Tsuga canadensis from Ontario. A small quantity of T. tchekiangensis Hous, has been received from China and

will be used to test the crossability of that species with T. heterophylla.

Forintek Canada, Vancouver, has conducted a study of the importance of tree size and stem form on the potential lumber-recovery value in order to set impartial standards for hemlock parent-tree selection. Forintek Canada continues to determine wood specific gravity for all possible parents to facilitate selection of parents for seed orchards and to establish a data base for correlations from progeny tests.

Cone-induction research using potted propagules was begun by the Ministry's Research Branch to expand on and refine techniques developed by the Canadian Forestry Service and Weyerhaeuser Co. (Ross et al. 1981). Results to date are very encouraging.

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# PHYSIOLOGY RESEARCH AND TREE IMPROVEMENT IN B.C. 1979-1981

J.E. Webber

*Ministry of Forests*
*Research Branch*
*Victoria, British Columbia*
*V8Z 5J3*

Key words: pollen, viability tests, pollination, boosting, cone enhancement, gibberellins, seed orchards, maturation.

The rapid establishment of Tree Improvement and Seed Orchard programmes in British Columbia is accelerating the need for developing and implementing physiology research results. Priorities have been established and two areas of research are being emphasized:

1) Pollen Management

Factors affecting harvesting, storage and reapplication of pollen are being considered. Pollination mechanisms, pollen flow, and resultant seed yields are being investigated to improve seed production and genetic value of seed orchard crops.

2) Cone Enhancement and Early Maturity

Cultural treatments known to affect coning response and their possible application for seed orchard management are being tested. In particular, gibberellin (G/A 4/7), fertilizer ($Ca(NO_3)_2$) and root pruning treatments are being examined for possible application to increase production by young seed orchard stock.

A second approach being investigated is the reduction of the non-coning, juvenile phase. Growth acceleration of germinants rapidly increases size, and may also accelerate sexual development.

Much of this research has been limited to Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) but programmes involving white spruce (Picea glauca (Moench) Voss) and lodgepole pine (Pinus contorta Dougl.) are being developed also. A brief summary of this research and current experiments is given below.

## POLLEN STORAGE AND VIABILITY TESTING

Maintaining pollen viability over its storage period is an integral part of all breeding and seed orchard programs. Because yearly production of pollen is not reliable, access to viable stored pollen can

facilitate yearly mating schemes and improve production and genetic value of seed from young orchards.

Freeze-drying techniques (Ching and Ching, 1964) adapted for Douglas fir pollen have been tested and can successfully maintain pollen fertility for at least four years, and perhaps longer. Two series testing three- and four-year old Douglas fir pollen confirm storage conditions: pollen dried to between two and six percent moisture content and stored at reduced temperatures (-26°C) in evacuated containers produces the highest filled-seed yield using controlled pollination techniques.

Series-one pollen was stored in flame-sealed ampules whereas Series-two pollen was stored in re-useable serum vials. No real difference in filled-seed set was observed for container type. However, pollen from evacuated, vacuum-sealed containers consistently produced better filled-seed yields than pollen from non-evacuated, airtight containers (63% versus 46% increases respectively over filled-seed yields from pollen stored in control containers).

Pollen viability tests involving adenosine triphosphate (ATP) analysis, conductivity measurements, germination assays, (Ching et al. 1975, Ching and Ching 1976) and tetrazolium stains have not correlated to field "fertility" tests (controlled pollination). Although these tests are useful for distinguishing live from dead pollen they can not be used to predict potential filled-seed yield. Work is continuing with other viability assays such as measuring respiration rates (Binder and Ballantyne 1975) in an effort to better understand the effect of pollen viability on pollination, fertilization and seed yields.

## SUPPLEMENTAL POLLINATION

Improving seed production and genetic value in Douglas fir seed orchards is possible by application of pollen to receptive strobili. However, results are largely dependent on time and method of application, and natural pollen supply.

To determine optimum receptivity of Douglas fir seed cones (measured as filled-seed yield), "boosting" was done at five dates as determined by the number of days beyond bud burst. No significant drop in filled-seed yield was observed up to six days after bud burst but the eighth day treatment was significantly lower. These results confirm that boosting should be done as early as possible to avoid competition from foreign, contaminating pollen and certainly within six days to realize maximum seed yields.

Application technique also affects results. Hand boosting allows greatest control and yields highest results but is labour intensive. Applying pollen from a helicopter is efficient but has yet to show a significant increase in seed yield over unboosted controls. The major problem with helicopter boosting is getting enough pollen to the receptive cones.

A third technique was developed to increase efficiency over hand boosting but also control the amount of pollen each tree received. A conical mist blower was built with a front and rear diameter of 1.22 m and 0.66 m, respectively, and a length of 1.83 m. An air stream moving from the face at about 20 kmph was created by a 0.61 m axial fan blade operating at approximately 1400 rpm. Pollen was forced into the air stream under 40 psi pressure. The cone was mounted on a trailer and pulled by a tractor. Significant increases in seed yields were observed and the results compared favourably to hand boosting.

Development of operational boosting techniques will continue in an effort to maximize seed orchard production and improve genetic value. Our next important question to answer is: what degree of contamination are we facing and can it be reduced by boosting?

## CONE ENHANCEMENT

Factors involved in the natural production of male and female strobili are not fully known. However, numerous research trials have shown that flower production can be affected by moisture stress, fertilizer application, hormone treatment and a variety of cultural techniques (root pruning, girdling, etc.)

To test the effect of hormone application on flower production by 11-year old half-sib Douglas fir seedling in a seed orchard, a solution of gibberellin 4/7 was fed "intravenously" through cut branch stubs on the third whorl. This test was superimposed on three levels of $Ca(NO_3)_2$. Within each block, treated trees were stratified as trees with a previous history of flowering and those without. Half of these trees were treated with gibberellin and the other half served as controls.

Gibberellin treatment resulted in an average three-fold increase in female strobilus production. No effect on male production was observed. Although calcium nitrate (225 and 450 kg/ha) increased seed cone production, the difference was not significant. In terms of overall production, trees with a previous history of flowering produced approximately three times more flowers than those trees without a history of flowering. For both classes of tree, gibberellin treatment resulted in an approximate three fold increase in coning.

Foliar spray treatments of GA 4/7 resulted in significant, 5-fold seed cone increases in 8-year old Douglas fir seedlings. The effect was not uniform, with largest increases observed on trees which had flowered previously.

In both trials, seed derived from trees induced to flower by GA treatments showed no significant differences in either filled-seed yileds, seed germination or early growth performance.

This work is continuing to better understand factors involved in coning response. Dr. Steve Ross, formerly with Weyerhaeuser, has now

joined our staff and will provide valuable experience in cone enhancement/induction research.

## EARLY MATURATION (ACCELERATED GROWTH)

Trials at Michigan State University indicate that accelerating the growth of spruce seedlings under 24 h photoperiod and 20° C may induce significant coning response within four years from seed (Young and Hanover 1976).

To test this approach, seed from white spruce parent trees was germinated and subjected to growth acceleration. After eight months, seedling height averaged 23.6 cm compared to 2.5 cm for controls. The accelerated seedlings and their corresponding controls are planted at two sites (Vernon and Saanich). These plants have now completed their third year of growth and the effect of both growth acceleration on the seedlings and site on growth and early maturation (coning response) will be monitored yearly.

A similar trial with lodgepole pine is now completing its accelerated growth stage and will assess response at several climatically different sites, plus compare the growth and coning response of grafts.

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# THE LODGEPOLE PINE IMPROVEMENT PROGRAM IN BRITISH COLUMBIA

Cheng C. Ying

*Ministry of Forests*
*Research Branch*
*Victoria, British Columbia*
*V8W 3E7*

Key Words: lodgepole pine, selection, breeding, flower production

Lodgepole pine occupies nearly 39 percent of the productive forest land and accounts for 32 percent of the mature timber volume in the interior region of British Columbia. An increasing annual harvest is now approaching 15 million $M^3$, next only to spruce. Over 11 million seedlings were planted in 1979, and it is estimated that annual planting will increase to over 40 million in the next decade. The importance of planting genetically-improved seed is, therefore, self-evident.

Although some northern parental selections were grafted and established in clone banks in the early part of the decade (see below), genetic improvement in lodgepole pine was started formally in 1975 (Wheeler 1978, 1980). Considerable progress has been made. This report presents a brief summary of progress on parent tree selection, breeding orchard establishment and information on flowering.

## PARENT TREES AND BREEDING ORCHARDS

The original plan delineated 4 selection units as target areas for breeding effort (Wheeler 1978). In general, these selection units represent a wet transitional zone with relatively high site productivities and/or high priority regions for intensive silviculture.

Five hundred and sixty-five parent trees have been selected. Figure 1 gives the number and location of the selections in each unit. They were grafted and planted in breeding orchards at Red Rock Research Station. The success of our grafting in the greenhouse was approximately 85 percent. Later survival of the grafts in breeding orchards is nearly 95 percent.

## FLOWER PRODUCTION AND GRAFTS

Flower production in the SK* and SCA* clonebanks has been recorded since they were established in 1972. The average number of female conelets and pollen clusters per flowering graft is summarized by year.

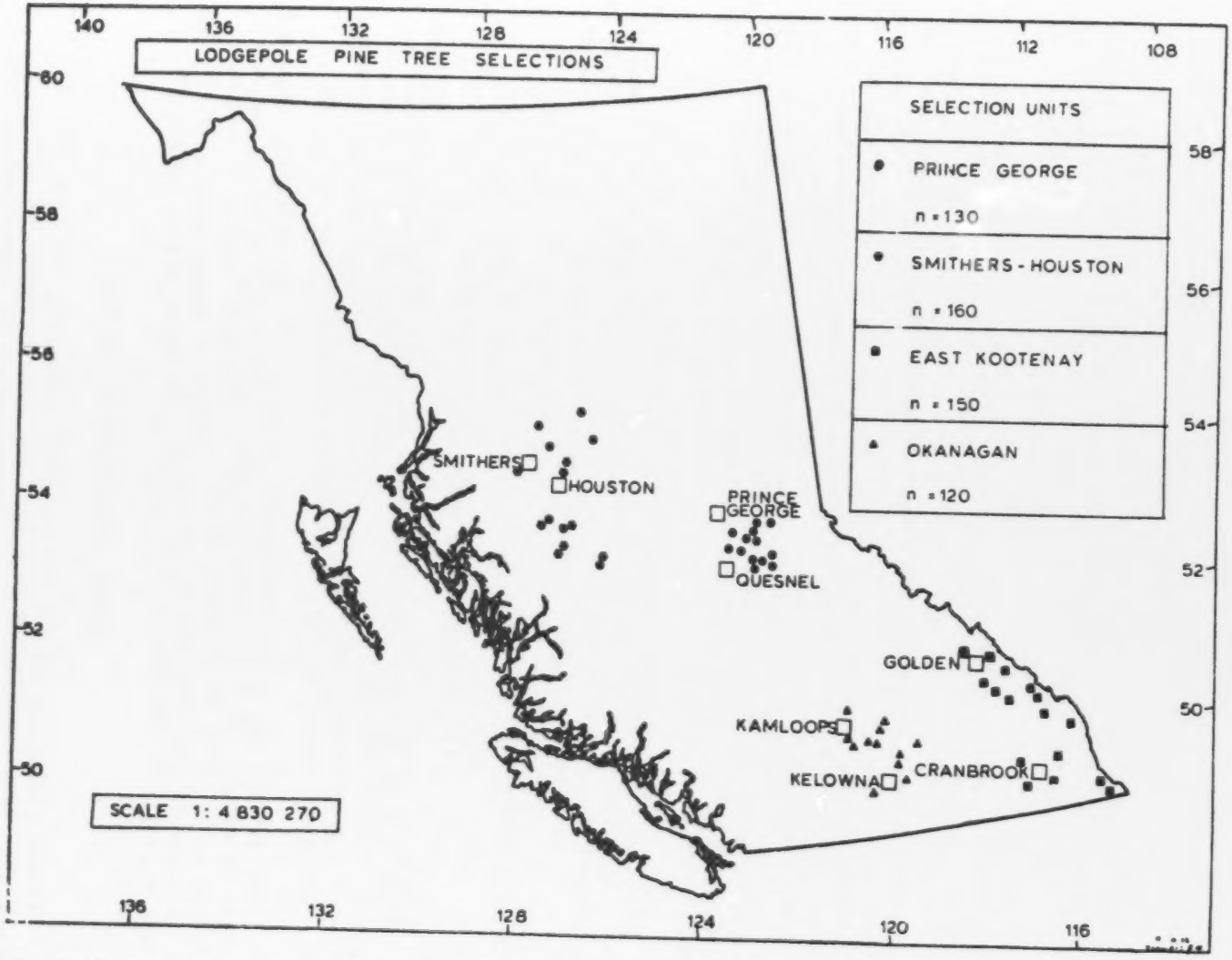


Figure 1. Lodgepole pine tree selections, British Columbia.

| Year | SCA Clonebank | | SK Clonebank | |
|---|---|---|---|---|
| | Female conelets | Pollen clusters | Female conelets | Pollen clusters |
| 1973 | 1 | 0 | 0 | 0 |
| 1974 | 2 | 0 | 1 | 0 |
| 1975 | 5 | 0 | 2 | 0 |
| 1977 | 18 | 0 | 3 | 0 |
| 1979 | 56 | 7 | 23 | 5 |
| 1980 | 86 | 7 | 63 | 10 |

Female conelet production increases steadily with age of grafts. All the living grafts (678) bore females in 1980, and produced a total of 49,571 conelets. Assuming 80 percent of them developed to mature cones, each averaging 20 seeds per cone, 693,134 seeds could be harvested in 1980. This suggests that as far as cone production is concerned, Red Rock is a suitable location for lodgepole pine seed orchards of at least central and northern origins.

On the other hand, only half of these grafts produced male strobili in 1980. However, there is no clear evidence that male flower production would be enhanced by either north - or southward-transfer.

## EFFECT OF ACCELERATED GROWTH ON FLOWERING

An exploratory study on the effect of continuous light on flower promotion was initiated in 1976 (Wheeler 1979). Seedlings grown under 24-hour daylength for 6 months were then outplanted in the Research Nursery at Red Rock. By the 4th growing season, 1980, the frequency of flowering trees and the average number of female flowers per flowering tree were roughly 600 percent greater for accelerated seedlings (81%, 18 flowers/tree) than for controls (12%, 3.6 flowers/tree). The control seedlings have yet to produce male flowers, whereas 18 percent of the "accelerated" seedlings produced an average of 10 male clusters in 1980.

* Most of the parent trees originated from north of Latitude 53°. They were selected by Professor O. Sziklai of U.B.C. for two Swedish forest companies, Stora Kopparberg (SK) and Svenska Cellulosa (SCA). The B.C. Ministry of Forests participated in the collection and processing of seeds and scions and established clone banks at Red Rock (Illingworth 1975). Eighty-three clones are included in the SK and 75 clones in the SCA collections. Five ramets of each clone were planted initially in the two clonebanks.

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# PROVENANCE RESEARCH BY BRITISH COLUMBIA FOREST SERVICE, 1977-1979

Cheng C. Ying

*Ministry of Forests*
*Research Branch*
*Victoria, British Columbia*
*V8W 3E7*

Key Words: provenance, genecology, Douglas fir, Sitka spruce, lodgepole pine, Abies.

Provenance research in British Columbia has been carried out by the B.C. Ministry of Forests since the early 1960's, when L. Roche made a genecological study of interior spruce and R.L. Schmidt established most of the present Douglas fir trials. Expansion of provenance research into other species was accomplished mostly during the period when K. Illingworth was in charge of the provenance research program. A total of 138 testing plots which cover 235.9 hectares has been established throughout the Province. Provenance research has been focussed on the major commercial species: Douglas fir, lodgepole pine, Sitka spruce and more recently, the true firs. Previously, establishment and maintenance received high priority to ensure the safety and quality of the tests. Future effort will emphasize the interpretation and practical application of information from these studies.

This report broadly outlines the provenance program and its highlights. Details were reported in papers by K. Illingworth in two volumes of the Proceedings of the IUFRO Joint Meeting, Vancouver, Canada, 1978, published by B.C. Ministry of Forests.

## STATUS OF THE PROVENANCE RESEARCH PROGRAM

The following table summarizes the extent and scale of the provenance trials of different species in this Province:

| Species | Number of Provenances | Number of Tests | Year of Establishment* |
|---|---|---|---|
| Douglas fir (Coast) | 88 | 35 | 1968 |
| Douglas fir (Interior) | 12 | 4 | 1970 |
| Spruce (Interior) | 40 | 7 | 1966 |
| Sitka spruce | 43 | 14 | 1973 |
| Lodgepole pine | 182 | 72 | 1971 |
| Grand fir | 23 | 4 | 1980 |
| Amabilis fir | 9 | 2 | 1980 |
| Noble fir | 23 | 10 | 1981 |

* Trials were often divided into series and established in different years.

Year listed refers to the oldest trials.

## LODGEPOLE PINE

The core of the lodgepole pine provenance program is the range-wide study which involves 150 provenances over 60 testing sites in the Interior region of British Columbia. The 60 sites are located in 12 regions representing 12 broad latitudinal and geoclimatic zones (Fig. 1). Sixty provenances were included in each test and 10 provenances are common to all the 60 sites.

The most recent assessment was done in 1979, 6 years after planting. Mean survival over the 60 sites was 91.6%, despite severe damage by various animals (horses, voles) at two sites and flooding at a third. Most sites had over 90% survival.

Height growth showed a very broad geographic pattern: provenances of coastal origin, and those from above latitude 60 degrees and below latitude 49 degrees had poor height growth. Excluding those provenances, no consistent geographic pattern can be established. For example, origins of the 10 tallest provenances averaged over the 5 sites in Region 8 (Fig. 1) cover a range of nearly 5 degrees of longitude (see table below). However, evidence suggests that the provenances from the interior wet belt are most vigorous as well as adaptable to a wide range of sites in the southern and central interior of the province.

The 10 Tallest Provenances Averaged over 5 Sites in Region 8.

| PROV. NO. | LOCATION | LAT. | LONG. | MEAN HEIGHT (cm) | RELATIVE HEIGHT C% |
|---|---|---|---|---|---|
| 14 | Wentworth Cr. | 50 58 | 120 20 | 171 | 123 |
| 42 | Champion L. | 49 11 | 117 35 | 168 | 121 |
| 45 | Settlers Rd. | 50 31 | 115 44 | 168 | 121 |
| 23 | Udy Cr. | 53 01 | 123 14 | 167 | 120 |
| 15 | Esperon L. | 50 03 | 119 39 | 163 | 117 |
| 1 | Trapping Cr. | 49 35 | 119 01 | 161 | 116 |
| 18 | Chilco | 51 39 | 123 45 | 160 | 115 |
| 19 | Nithi R. | 54 03 | 125 05 | 160 | 115 |
| 17 | Oie L. | 52 00 | 121 12 | 160 | 115 |

## DOUGLAS FIR

The Douglas fir provenance study consists of four series:

(01) A range-wide collection of 77 provenances tested in 5 coastal climatic zones to determine geographic variations and to compare their adaptability and vigour in constrasting environments;

(02) Five pairs of low and high elevation provenances planted at 6 sites spanning a range of elevation from 60 to 1035 m. to test the feasibility of seed transfer across altitudinal intervals;

Figure 1. Location of Pinus contorta provenance trials.

(03 Five provenances selected from a wide geographic area plus one or two local sources, tested at 22 sites representing a wide range of site conditions, to assess provenance x site ineraction and to identify hardiness zones:

(04) To compare select coastal and interior provenances at high elevation sites, four interior wet-belt and 3 coastal high elevation provenances are tested at 3 high elevation sites (750-975 m) on Vancouver Island.

Figure 2 shows the locations of the test sites.

Field performance in terms of hieght growth differed significantly among provenances. The range of differences was wider in the less rigorous environments. Despite this considerable variation in provenance mean height, the pattern with respect to geographic origin is not well defined.

The importance of altitudinal transfer of seed sources became obvious only at the highest elevation site (Lookout Mtn., 1035 m) and the lowest elevation site (Oyster River, 60 m) (Fig. 2, Series 02); high elevation provenances were generally taller than the low elevation ones at Lookout Mtn. and vice versa at Oyster River. No difference in growth was found between high and low elevation provenances at the other 4 intermediate elevation sites. The results indicate that seed can be transferred across a considerable range of elevations without serious consequences.

In general, provenances from the Coastal Western Hemlock (CWH) zone (Klinka et al 1979) outgrew those from the drier coastal Douglas fir (CDF) zone at sites located in CWH or CDF zones. In coastal British Columbia, CWH provides optimal growth environment. Douglas fir stands in this zone must overcome severe competition from the climax dominant species in order to become established. Natural selection would favor the genotypes with vigorous vegetative growth.

## SITKA SPRUCE

Three series of field tests were established throughout coastal British Columbia. The test selections were from among 43 populations spanning a latitudinal range of 17 degrees from Brookings, Oregon, to Yakutat, Alaska.

Survival was better than 90 percent at all 13 test sites 3 years after planting. Strong clinal variation, inversely correlated with latitude and distance from the Coast, was shown in growth, winter injury and time of bud flushing. Introduction of provenances from as far south as the Oregon Coast will markedly increase the yield of Sitka spruce plantations on Vancouver Island and the Queen Charlotte Islands. However, the tests are very young. Prudence calls for the continued use of local seed sources, particularly for planting cold, mainland valleys.

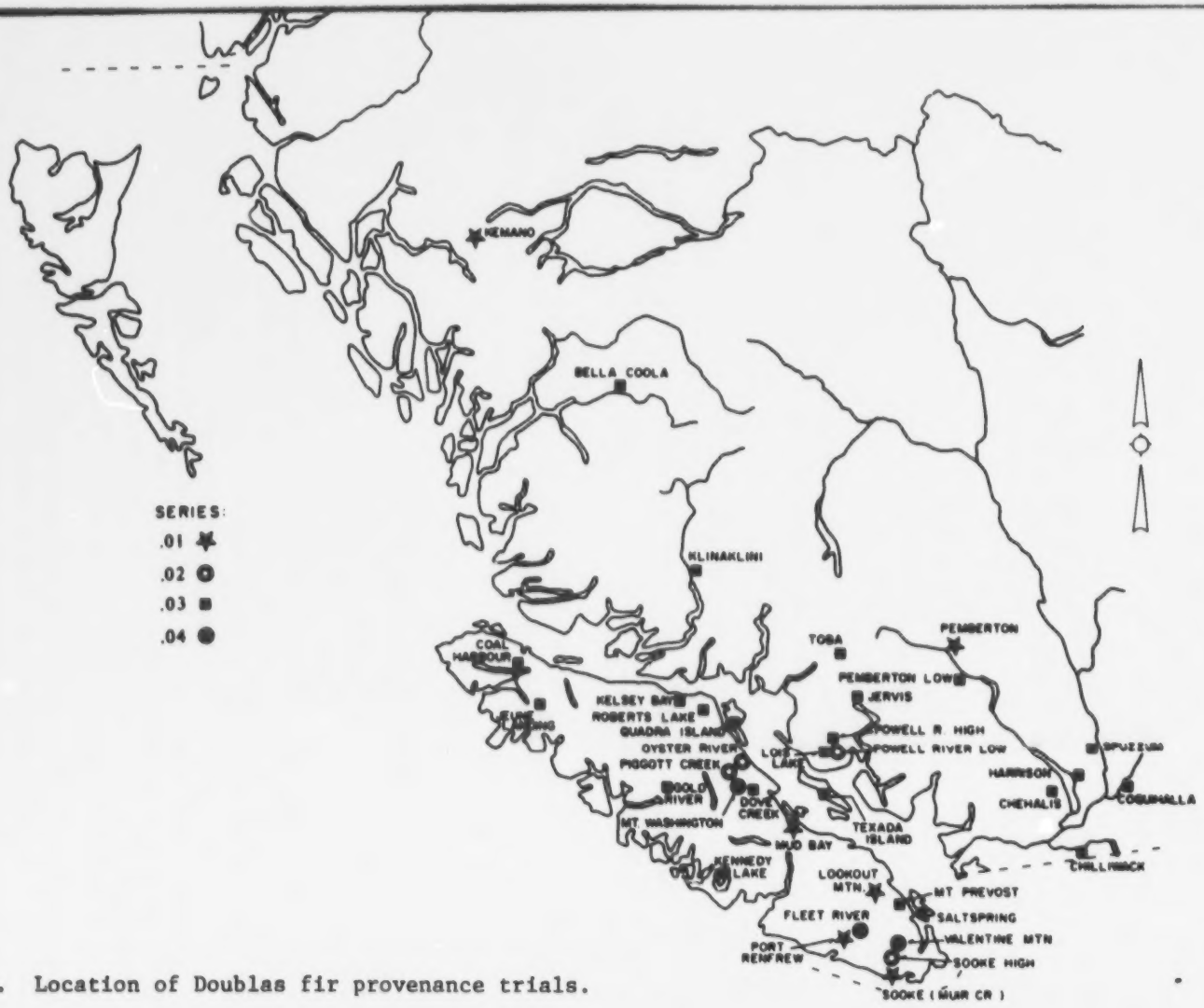


Figure 2. Location of Doublas fir provenance trials.

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# TREE SEED RESEARCH, PACIFIC FOREST RESEARCH CENTRE 1979-1980

D.G. Edwards, J.R. Sutherland and G.E. Miller

*Pacific Forest Research Centre*
*Canadian Forestry Service*
*Victoria, British Columbia*
*V8Z 1M5*

Key Words: seed prechilling, moisture content, seed fungus, seed blight, spruce cone rust, Douglas-fir cone gall midge, Douglas-fir cone moth, spruce seedworm

This report describes the work of D.G. Edwards on redrying and storage of seeds of Abies (Mill.) species, and the official seed testing program at Pacific Forest Research Centre. It also covers the studies of J.R. Sutherland on the seed fungus (Caloscypha fulgens (Persoon) Boudier), seed-borne Sirococcus blight (Sirococcus strobilinus Preuss), and inland spruce cone rust (Chrysomyxa pirolata Wint.). The research work of G.E. Miller (replacing A.F. Hedlin) on the Douglas-fir cone gall midge (Contarinia oregonensis Foote), the Douglas-fir cone moth (Barbara colfaxiana (Kearfott)) and the spruce seedworm (Cydia youngana (Kearfott)) is described also.

## IMPROVING THE USE EFFICIENCY OF SEEDLOTS

D.G. Edwards

Work has concentrated on determining how long prechilled (stratified) seeds can be stored and the optimum moisture content during prechilling. It has been shown (Edwards 1980a) that prechilled seeds of Abies amabilis (Dougl.) Forbes, A. grandis (Dougl.) Lindl., and A. lasiocarpa (Hook.) Nutt. can be stored in a refrigerator for 12 months without any significant reduction in germination, if they are dried to a moisture content of 25% (of fresh weight). Similar results have also been obtained for Abies procera Rehd. seeds (Edwards, unpublished).

In 28-day, standard germination tests, seeds dried to 35% after a 4-week prechill treatment germinated best of all, with final germination percentages being significantly higher than in seeds at other moisture levels. However, they could not be reliably stored for 6 months, since germination usually began in the refrigerator beyond that time. When dried to 35% and stored for at least 3 months, germination was essentially complete, i.e., within 0.5% of the final germination

percentage, by the 14th day of the test. These germination rates were approximately 2-7 times greater than in seeds prechilled, but not dried or stored, and were 6.5-17 times greater than in unprechilled seeds. Other trials on approximately 30 additional A. amabilis seedlots have confirmed that drying prechilled seeds to 35%, followed by 3 months' cold storage, produces better germination than prechilling alone (Edwards and Leadem, B.C. Min. of Forests, unpublished).

These increases in germination should be advantageous in the nursery, even if there is no requirement per se to store prechilled seeds. Aside from germination increases, prechilling could be applied relatively independently of sowing day; e.g., a 1-month prechill could begin anytime up to 6 months before sowing. As a corollary, sowing date would become more flexible since there is a period of several months in which seeds can be stored without germination beginning prematurely (Edwards 1980b).

A field trial of the procedure, using 150,000 A. amabilis seedlings in a container nursery, has been undertaken collaboratively with the B.C. Ministry of Forests at Campbell River on Vancouver Island. Early results show that seeds dried to 35% and stored for 3 months germinated 2-10 times faster during the first 2 weeks after sowing than seeds prechilled 2 or 3 months (but not dried or stored). The differences decreased by the 4th week after sowing.

## CONE AND SEED DISEASE RESEARCH

Jack R. Sutherland

Research continues on the seed fungus (Caloscypha fulgens), seed-borne Sirococcus blight (Sirococcus strobilinus) and inland spruce cone rust (Chrysomyxa pirolata). Recent research on the seed fungus showed several differences between the isozyme patterns of disease-free and pathogen-infested samples, but the main difference was in the latter's high alkaline phosphatase (ALP) activity. By using gel electrophoresis a qualitative analysis was developed, based on presence or absence of ALP, to distinguish infested from disease-free seedlots, and the high ALP activity of infested samples was determined to be of pathogen origin. A qualitative assay for disease incidence was developed by determining the ALP activity of samples with known numbers of diseased seeds and using a prediction equation relating enzyme activity to diseae incidence. A Can. J. For. Res. paper is in press.

Work on Sirococcus blight demonstrated that it is seed-borne on spruce in coastal B.C. container nurseries. The pathogen was detected in over 60% of the spruce (interior and Sitka) seedlots with blight histories. The pathogen was present in 0.3-3.1% of the seeds of infested seedlots. Seeds with shrunken contents yielded the pathogen 7-9 times more often than seeds with normal-appearing contents. A paper has been accepted for publication in Can. J. Botany.

Studies (Can. For. Serv. Res. Notes, in press) over the past 3 years show that cone rust drastically reduces seed production and that seeds from diseased cones often germinate abnormally. Significant progress is being made in determining the exact sequence of events in the pathogen's life history, and the ecology and methods for eradicating the rust's alternate hosts.

## CONE AND SEED INSECT STUDIES

G.E. Miller

Mr. A.F. Hedlin retired in December, 1979. The study is now lead by Mr. G.E. Miller. Sampling techniques are being developed for Douglas-fir cones and Douglas-fir cone gall midge (Contarinia oregonensis) eggs. Evidence for a sex pheromone in cone gall midge has been collected and a chemical identification program has begun.

Studies on attraction in Douglas-fir cone moth (Barbara colfaxiana) have shown that the optimal blend of Z-9-dodecen-1-ol: Z-9-dodecen-1-yl acetate is 75:25. The effects of factors such as trap height, trap design, trap colour, attractant dispenser, and release rates on trap catches are being studied. Studies on host attractants of Douglas-fir cone moth have been temporarily discontinued. Studies on sex and host attractants in the spruce seedworm (Cydia youngana) are continuing but have been inconclusive to date.

Several insecticides have been screened for effectiveness against Douglas-fir cone and seed insects but none were consistently effective. Delayed flowering is sometimes effective in reducing cone gall midge damage but is not a reliable control technique.

Dr. T.S. Sahota is studying aspects of the induction of prolonged diapause in the Douglas-fir cone moth, namely: i) attempts are being made to physiologically differentiate pupae entering prolonged diapause from those that diapause only one winter, and ii) cone producing and non-producing trees are being examined to determine if such trees differ chemically and if they do, whether or not chemical constituents of the host affect induction of prolonged diapause. Preliminary results indicate that producing and non-producing trees differ in their isozyme complexes, specifically in the quantities of total proteins, acid phosphatase and esterase.

## OFFICIAL TESTING OF TREE SEEDS

D.G. Edwards

Since the Pacific Forest Research Centre became an official member of the International Seed Testing Association (ISTA) in 1978,

official testing of commercial seedlots has increased markedly. Certificates of seed quality for 107 seedlots, from eight species, were issued during 1979/80 and an additional 152 tests were completed on seedlots not requiring certificates.

| | Number and type* of certificate | | | |
|---|---|---|---|---|
| | 1979 | | 1980 | |
| | Blue | Orange | Blue | Orange |
| Abies grandis | | | 1 | |
| Picea glauca | | | 4 | |
| Picea pungens | | | 1 | |
| Picea sitchensis | | | 1 | |
| Pinus caribaea | 1 | | 2 | |
| Pinus contorta | 5 | 19 | 36 | 26 |
| Pseudotsuga menziesii | | | 9 | |
| Thuja plicata | | | 2 | |
| Total | 25 | | 82 | |

* "Blue" certificates apply only to the sample submitted by the owner. "Orange" certificates require official sampling and sealing of the container and the test results apply to the entire seedlot.

Almost all the seedlots tested were also certified for Source Identity under the OECD Regulations (see report by D.F.W. Pollard).

A "Seed Bulletin", an informally written newsletter, was created in 1980 primarily as a means of communication with seed dealers in the Pacific region on such matters as clarification of certification and seed testing rules and regulations, sample sizes, lead-in times for test completion and recent publications. Bulletins will be issued irregularly and will be sent to other seed analysts and inspectors throughout the CFS for informational purposes.

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# TREE AND SEED IMPROVEMENT AT THE PACIFIC FOREST RESEARCH CENTRE

D.F.W. Pollard

*Pacific Forest Research Centre*
*Canadian Forestry Service*
*Victoria, British Columbia*
*V8Z 1M5*

Key Words: western hemlock, provenances, flower enhancement, gibberellins, reproductive morphology, seed certification.

A project entitled PC-49 Tree and Seed Improvement: BC and Yukon Conifers was established in 1978 to provide a comprehensive range of research and services for improving gene resources in BC and the Yukon. Research during the past two years has been focussed on a large provenance trial of western hemlock Tsuga heterophylla (Raf.) Sarg., and on flower enhancement methods for this species. Good progress has also been made with guidelines for reproductive bud recognition and isozyme characterization methods for western conifers, particularly lodgepole pine. Seed certification services have been maintained and elaborated where necessary, and Regulations for Forest Tree Seeds pertaining to the revised Canada Seeds Act have been drafted. Progress on these items is outlined below; a separate report on seed research and testing services has been submitted by D.G.W. Edwards.

## WESTERN HEMLOCK PROVENANCE TRIAL

The Canadian Forestry Service, in collaboration with forest industries in BC, established a trial of 15 provenances of western hemlock at four test sites on Vancouver Island in 1971. After inspection in 1979, one of the test sites (Quatse Lake) was cleared of an excessive invasion of naturally-seeded seedlings through a cooperative agreement between the CFS, the BC Ministry of Forests and Western Forest Products Ltd. (formerly Rayonier Canada Ltd.).

The ten-year height and dbh measurements were made at all sites in spring 1981 and will be reported at a future date. A full analysis of all unpublished data is also planned. Height measurements were made in 1971, 1972, 1973, 1974, 1976 and 1977.

Within- and among-provenance variations in important juvenile characters (flushing and growth cessation) have been investigated among open-pollinated families of parent clones of the original provenance collections. These too will be reported later.

Seeds of Tsuga chinensis (lat. 33.2°N, long. 107°E, elev. 1700 m) have been received from Nanjing, Peoples Republic of China, and will be used to expand the Tsuga arboretum at this Centre.

## FLOWER ENHANCEMENT

The combination of gibberellic acid ($A_{4/7}$) and fertilizer ($Ca(NO_3)_2$) has proved to be effective in the enhancement of strobilus production in young seedlings and rooted cuttings of western hemlock. Against this now routine treatment we have successfully superimposed other treatments, in particular moisture stress (Holger Brix) and temperature (author). High moisture stress and high temperature both contribute to strobilus enhancement, to the extent that, without proper consideration of these factors, strobilus production may be quite limited. Results of these investigations will be published shortly.

Experiments have also been conducted into the optimum timing of enhancement treatments, the effects of late-season temperatures, and the combined effects fo photoperiod and thermoperiod. Again results will be published as warranted.

## RECOGNITION OF REPRODUCTIVE STRUCTURES

A series of leaflets describing the reproductive morphology of western conifers is being prepared by Slavoj Eis. While the primary need for such materials has been felt in the cone crop assessment scheme in the Region, the leaflets are expected to receive a wider audience concerned with tree improvement, seed orchard management, and forestry education. The series is to be produced as self-explanatory leaflets that may be tied together with an introductory section and title covers. Leaflets are currently available for four species (see publications).

Cone Crop Bulletins were published in 1980 and 1981 for the Pacific and Yukon Region. A more intensive forecasting system is under development for southern Vancouver Island, and a pilot inventory of lodgeple pine seed resources is to be conducted in the Yukon.

## BIOCHEMICAL CHARACTERIZATION OF SEEDS

Isozyme analysis has been improved through the acquisition of iso-electric focussing equipment. A series of lodgepole pine seedlots with known terpenoid patterns are currently under study, together with two sets of 100-tree collections representative of two interior stands. The investigator, Eleanor McMullan, has been accepted for PhD studies at the Swedish University of Agricultural Sciences, Umea, beginning August 1981.

## CERTIFICATION OF FOREST TREE SEED UNDER THE O.E.C.D. SCHEME

As Certifying Authority for the Pacific and Yukon Region of the CFS, seed inspectors of this Centre inspected and certified the following quantities of seed for export:

| | 1979 - 80 | | 1980 - 81 | |
|---|---|---|---|---|
| | No. of certificates | Total wt. (kg.) | No. of certificates | Total wt. (kg.) |
| Pseudotsuga menziesii | 31 | 448.4 | 22 | 220.8 |
| Pinus contorta var.latifolia | 66 | 603.4 | 116 | 1173.0 |
| Pinus ponderosa | 3 | 53.4 | - | - |
| Pinus monticola | - | - | 1 | 14.9 |
| Picea sitchensis | 44 | 932.2 | 25 | 569.0 |
| Picea engelmanni | - | - | 1 | .35 |
| Tsuga heterophylla | - | - | 2 | 3.8 |
| Abies amabilis | 2 | 12.9 | - | - |
| Abies lasiocarpa | - | - | 1 | 2.3 |
| Total | 146 | 2050.3 | 168 | 1984.15 |

All the above seedlots were certified for Source Identity. Regulations for other O.E.C.D. categories of seed are in preparation.

The certifying officer participated in the 1980 Biennial Meeting of the O.E.C.D. Representatives of Designated Authorities in Paris, and the IUFRO Working Party Meeting" Pinus contorta as an exotic species" in Norway and Sweden, August 1980.

## REGULATIONS FOR FOREST TREE SEEDS

Regulations pertaining to the revised Canada Seeds Act (awaiting passage through the Canadian parliament) have been drafted and are under review. The Regulations as envisaged call for active involvement of the CTIA in establishment of standards for certain categories of seeds. A more thorough debate of the issue is expected in the next two years.

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# MACMILLAN BLOEDEL LIMITED PROGRESS REPORT 1980-1981

R.C. Bower

*Forest Geneticist*
*Woodlands Services Division*
*MacMillan Bloedel Limited*
*V9R 5H9*

Key Words: seed orchards, clonebanks, progeny tests, provenance tests

MacMillan Bloedel Limited has been involved in several tree improvement/forest genetics activities during the period covered by this report. These activities have included seed orchard establishment, clonebank management and progeny and provenance test measurements.

## SEED ORCHARDS

The establishment and essential completion of five clonal Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco var. menziesii) seed orchards continued on the Company's two seed orchard sites. These orchards are established primarily for Company use.

MacMillan Bloedel Limited is a member of the Coastal Tree Improvement Cooperative (C.T.I.C.) and is committed to establishing and managing an additional four clonal seed orchards:

- western hemlock (Tsuga heterophylla (Raf.) Sarg.)
- amabilis fir (Abies amabilis (Dougl.) Forbes)
- western redcedar (Thuja plicata Donn)
- yellow cypress (Chamaecyparis nootkatensis (D. Don) Spach)

Activities related to these orchards have been restricted to parent tree selection and propagation.

## CLONEBANKS

The Company is also managing both a western hemlock and a poplar/willow clonebank within the C.T.I.C. The western hemlock clonebank is comprised of rooted and grafted ramets of the same clones. This clonebank will allow study of the growth habits and seed production of the two types of propagules. The poplar/willow clonebank is comprised of 56 Salix species and cultivars, 11 black cottonwood (Populus trichocarpa Torr & Gray) parent tree selections and 16 Populus species and cultivars. The primary function of this clonebank is to provide cuttings for use in streamside stabilization.

## PROGENY TESTS

### Western White Pine (Pinus monticola Dougl.)

This test was initiated in 1978 to evaluate, under plantation conditions, the open-pollinated progeny of selected white pine trees. Parent trees were selected as being either rust free, rust cankers inactivated in the branches or infected with active rust. Plantations were established on two sites considered potentially good white pine reforestation sites.

In 1980, after two years in the field, the trees were assessed for survival, height growth and rust incidence. Survival has been excellent and only one site is showing any signs of rust infection. On that site there appears to be no difference in the rust infection levels of the three groups. Each group has 40% of the families showing some rust incidence.

Analysis of variance of the height data identified a highly significant (.01) location effect and location x family interaction. The plantation will be assessed again in 1982.

## PROVENANCE TESTS

### Noble fir (Abies procera Rehd.)

Plantations were established in the fall of 1977 on five sites to test the potential value of noble fir as a timber species on Vancouver Island. Six noble fir provenances from Washington and Oregon were used in a randomized complete block design with 25-tree row plots. Four replications were planted at each test location. Statistical analysis of the survival data after two growing seasons showed highly significant (.01) differences between locations and provenances. As an example, one test had a mean survival of only 33%, while two provenances in that test had survivals of 86% and 78% respectively.

Species comparison tests were established in conjunction with the noble fir provenance tests. Species additional to noble fir were: amabilis fir, Douglas-fir, western hemlock, mountain hemlock (Tsuga mertensiana (Bong.) Carr.) and western larch (Larix occidentalis Nutt.). These tests were established as randomized complete blocks with 25-tree row plots and four replications at each site. Survivals were assessed at the same time as the provenance tests. Statistical analysis showed highly significant (.01) differences between locations and species. Noble fir had survival equal to or greater than the other species in all plantations. This test will receive fifth year measurements in 1982.

Western Larch

Four plantations were established in the fall of 1977 with the objective of determining the performance of four provenances of western larch on a variety of sites. Four provenances from high quality stands in southeastern British Columbia were used. A randomized complete block design was used with 25 trees per provenance, replicated four times per site.

Survival after two growing seasons was assessed and statistical analysis showed significant differences (.05) between locations and provenances. However, only one provenance in one location had a survival rate as high as 80%.

Species comparison tests were established along with the provenance tests. Species included were western larch, Douglas-fir and lodgepole pine (Pinus contorta Dougl. var. contorta). A randomized complete block design with 16-tree row plots and two replications per site was used for this test. These tests were assessed at the same time as the provenance tests. Overall survivals were lodgepole pine - 76%, western larch - 66%, and Douglas-fir 34%.

# STUDIES IN NATURAL POPULATIONS OF SOME NORTH AMERICAN *ABIES*

Jack Maze

*Department of Botany*
*University of British Columbia*
*Vancouver, B.C. V6T 1B2*

Key words: *Abies*, population differentiation, population variation,

This report outlines work done in conjunction with Dr. W.H. Parker, Lakehead University, Thunder Bay, Ontario. The objectives of these studies are: 1) to determine patterns of relationships and variation of trees growing in nature, and 2) relate those patterns to variables that describe the environment and growth habits of the trees. Such information is of relevance in understanding the biology of forest trees, identifying potential sources of variation that may have an impact on re-forestation decisions, and identifying sources of certain genetic material for breeding experiments.

Over the last two years, studies have centered on *Abies amabilis* (Dougl.) Forbes and *A. lasicoarpa* (Hook.) Nutt. in the Nass River drainage, north of Terrace, B.C., *A. lasiocarpa* and *A. balsamea* (L.) Mill. in western Canada, *A. procera* Rehd. and *A. magnifica* A. Murr. in the Cascade, Coast and Sierra Nevada Mountains of western United States and *A. balsamea* in western Ontario. As well, preliminary analyses have been performed on combined samples of *A. lasiocarpa* and *A. balsamea* from Vancouver Island and western Washington east through the Rocky Mountains of Canada to western Saskatchewan and western Ontario.

Analyses have been based on population samples; the material being analyzed consisting of cones, needles from cone-bearing branches and, for most studies, needles from immature trees. Most of the data gathered have been structural; we have some chemical data. The data have been subjected to multivariate analyses.

Specific findings are listed below

1) Abies amabilis and A. lasiocarpa from the Nass River drainage.

a) The two species have not hybridized.
b) Population differentiation is related to edaphically odd sites (lava beds), physiographically sites of restricted areal distribution (canyon bottoms) and geographic distribution.
c) Immature trees show the same patterns of relationships as the mature.
d) Populations of immature trees are less variable than populations of sexually mature trees from the same site. This has been interpreted as reflecting more age-classes in the populations of sexually mature trees.

2) Abies lasiocarpa and A. balsamea from western Canada

a) The two species represent two poorly differented taxa that meet at the Rocky Mountains and not in central Alberta as has been previously hypothesized.
b) There is no indication of modern hybridization between the two taxa.
c) Population differention that occurs is not related to environmental variables. It could represent selective forces in ecologically different sites, or factors other than selection.
d) Points a) to c) above are based on structural data. Chemical data does not refute the above except that it indicates that geographic distribution is related to population differentiation.

3) Abies procera and A. magnifica

a) Based on analyses of needle data, both from cone bearing branches and immature trees, these two species are separate with the southern limit of A. procera and northern limit of A. magnifica being in southern Oregon in the vicinity of Crater Lake. Based on cone characters, these two species form an intergrading series connected by A. magnifica var. shastensis Lemmon in n. California and s. Oregon.
b) Population differentiation is related to geographic distribution as well or site history (i.e., whether or not populations became established following deforestation, either by logging or fire). Periodic disturbance is a common feature of forests in North America. Thus, one is led to the hypothesis that some types of population differentiation are cyclic in nature indicating that selection, like drift, can produce cyclic changes in gene frequency.

c) Populations of mature trees are more variable than populations of immature trees from the same site (see discussion under 1) d) above).
d) The combination of c) and b) above would imply a high degree of genetic heterozygosity in Abies procera and A. magnifica, and perhaps other trees.
e) The taxon called A. magnifica var. shastensis is polyphyletic (has evolved from more than one ancestor).

4) Abies balsamea from western Ontario

a) Population differentiation has occurred but is not readily explainable by any enviromental variable.
b) The relationships between populations of immature trees are not the same as the relationships between populations of mature trees.
c) Based on a) and b) above, it is hypothesized that selection does not explain population differentiation.

5) Abies lasiocarpa and A. balsamea from Vancouver Island and western Washington to western Ontario

a) These data were collected over several different years so analyses were done on residuals derived from multiple regression analysis. This was done to remove the effect of covariates (and hopefully size).
b) The data indicate that differentiation within A. lasiocarpa and A. balsamea, excluding plants from Vancouver Island, is weak at best. Plants from Vancouver Island are distinct from the rest.
c) These results are preliminary only and further interpretations must await more thought, analysis and data. However, it is interesting to note that, like Hunt and vonRudloff (1979), our data indicates A. lasiocarpa from Vancouver Island is different from the remainder of A. lasiocarpa and A. balsamea.

d) Cone data are not yet complete.

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# FOREST GENETICS AND TREE BREEDING AT THE FACULTY OF FORESTRY, UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER

O. Sziklai

*University of British Columbia*
*Faculty of Forestry*
*Vancouver, British Columbia*
*V6T 1W5*

Key Words: forest genetics, education, isozyme, variation, karyotype.

## UNDERGRADUATE PROGRAM

Beside the usual elective Forest Genetics course offered to undergraduate students, a similar course was given to 78 3rd and 4th year undergraduate students at the Nanking Technological College in China from September 16th to October 15th, 1980.

As a result of increased interest in tree improvement in British Columbia, a Guided Independent Study course in forest genetics is now in preparation.

## GRADUATE AND RESEARCH PROGRAM

Research programs relate to variation and heritability studies of western conifers, and graduate programs generally have correlated with the above objectives. Completed graduate programs included El-Kassaby's Ph.D. dissertation - who was the 9th student to receive Ph.D. degree in forest genetics on "Isozyme Patterns of a Selected Pseudosuga menziesii (Mirb.) Franco Population".

Open pollinated seed samples were collected from 42 Douglas-fir trees in September 1978. The indivduality of cone lots and subsequent seed lots had been retained in these trees. The trees are located in the University of British Columbnia Research Forest, Haney, B.C. and were studied previously for phenology, growth, and flower and cone production by Griffith (1968)

Isozyme variations were studied (using the gel electrophoresis technique) for both the haploid megagametophyte and the diploid embryo tissues at 27 loci, coding for 18 different enzymes for each tree separately.

The objectives of this study were:

1. to study the mode of inheritance for these loci;
2. to determine the linkage relationships among these loci;
3. to estimate the outcrossing rate (t) for this popluation;
4. to determine the most effective sample size for estimating allelic frequencies
5. to study the amount and organization of isozyme variation in this population and compare the results with the variation for some quantitative traits, and
6. to study the association between isozyme genotypes and quantitative traits.

The results from the inheritance analyses for the 14 heterozygous enzyme systems showed that these electrophoretic variants segregated in a co-dominant fashion with distinct simple Mendelian expression. The linkage study yielded two tightly linked pairs (AAT-2;PGI-2) and (AAT-3:SOD) with recombination frequencies of 1.5 and 22.4 percent respectively. In addition, 7 loosely linked pairs were detected with recombination frequencies varying between 32.7 and 41.9 percent. It was not possible to study three-point linkage due to the lack of appropriate combinations. Conditional probabilities were used to estimate the outcrossing rate (t) in the population using 4 enzyme systems. The estimated outcrossing rate was 0.9 with a standard deviation of 0.11, giving an inbreeding rate of 10 percent. By the minimum sampling criterion it was estimated that sample sizes between 42 and 60 trees from the base population are optimal to obtain reliable estimates for the allelic frequencies. Striking agreement on the appointment of genetic variation was found between results obtained from the gene diversity analysis for the electrophoretic data and the analysis of variance for 7 different quantitative traits. These 2 independent sets of informaton confirmed that the majority of the variation existed within and not between poplulations Finally, the association between the mother trees' genotypes and the performance of their half-sib families showed that the mother trees appeared to exert minimal influence on those characteristics analyzed. The pollen parent contribution to the genetic constitution of the progenies should be investigated and it is recommended that isozyme studies should be extended to full-sib progenies.

Nelson, M.F. thesis was the 11th in forest genetics and he investigated the "Variation in Growth Efficiency of Selected Western Hemlock [Tsuga heterophylla (Raf.) Sarg.]Trees.

Eighty western hemlock trees, in the age range of 15 to 48 years, were selected on three Crown Zellerbach tree farms in northwestern Oregon and southwestern Washington to sample the range of variation in growth efficiency. Growth efficiency is defined as the ability of the crown to produce the maximum amount of wood in relation to its crown surface area. Seclection of the trees was based on the crown index ratio (live crown length/crown width).

The objectives of the study were to estimate:

1) the range of variation in growth efficiency of invididual trees,
2) how variation in growth efficiency of individual trees could be utilized to maximize volume on a unit area, and
3) the efficiency of narrow crown western hemlock trees as wood producers.

Results from regression analysis showed that there was sufficient variation in growth efficiency, with a range of the standardized residuals exceeding at least ±2.0 standard errors of the estimate for all three regression models. Based on this range it is suggested that selection of ten year basal area increment or gross stem volume for western hemlock in relation to crown surface area or sapwood basal area may be worthwhile.

The significance of the variation in growth efficiency becomes apparent when the higher growth efficiency classes are selected. It is estimated that selection of the higher growth efficiency classes rather than the average may increase ten year basal area increment/hectare by 39 to 45 percent.

It appears from the trees measured that there is little relationship between growth efficiency and the degree of slenderness of the crown.

Presently Musoke is close to completing her M.F. thesis on "Junvenile-mature Correlation of Selected Douglas-fir Provenances and Progenies", and Collangeli now has samples from seven of the eight Pseudotsuga species to complete her M.Sc. thesis on "Comparative Karyotype Analysis of Pseudotsuga Genus".

Dr. Y.A. El-Kassaby is writing up his research results for publication, assisting undergraduate and graduate students in their thesis preparation as a NSERC Postdoctorate Fellow.

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# TREE IMPROVEMENT IN ALBERTA, 1979-1981

N.K. Dhir, F.W. Daniels, and W.D. Baker
*Alberta Forest Service*
*Edmonton, Alberta T5K 2C9*

D. D'Amico
*Simpson Timber Company (Alberta) Ltd.*
*Whitecourt, Alberta T0E 3L0*

D.T. Young
*Procter and Gamble Cellulose, Ltd.*
*Grande Prairie, Alberta T8V 3A9*

B. Zak
*British Columbia Forest Products Ltd.*
*Grande Cache, Alberta T0E 0Y0*

B.P. Adams
*Canadian Forest Products Ltd.*
*Grande Prairie, Alberta T8V 3A3*

Key Words: selection, tree breeding, seed orchards, seed production, lodgepole pine, white spruce.

The Alberta tree improvement program is in its sixth year of operation. During this period, the interest, acceptance, and participation by the forest industries in the program work and related activities has steadily increased. As a result, the work on several projects on genetic improvement of lodgepole pine and white spruce, although still in planning or very early stages, has progressed very well. This report very briefly describes progress on the work carried out by the Alberta Forest Service, British Columbia Forest Products Ltd., Canadian Forest Products Ltd., Procter and Gamble Cellulose, Ltd., and Simpson Timber Company (Alberta) Ltd. over the past two years.

## PROGRAM DEVELOPMENT

The FMA forest industries and the Alberta Forest Service held a series of meetings to finalize details relating to obligations, roles, and responsibilities of the participants in the co-operative tree improvement projects. Agreement was reached in principle, with regard to sharing of costs and work loads for various activities and phases, with the exception of seed orchards. A formal agreement was signed by British Columbia Forest Products Ltd. and the Alberta Forest Service affirming commitment of both parties to work co-operatively to initiate and carry out work on specified projects; and the description of cost and work sharing arrangements was provided. The same agreement is expected to be formally agreed bilaterally by the Forest Service and each of the other FMA forest industries.

The work on several projects is at a stage where commitments of sizeable resources are required on part of the forest industries to ensure continuation and successful completion of work under progress. The industries collectively approached the Forest Service for incentives in return for carrying out genetic tree improvement and intensive silviculture work. A Silviculture Improvement Advisory Committee, consisting of members from industry and the Alberta Forest Service, was formed to explore this issue in depth and make recommendations. Separately,

the Alberta Forest Service and FMA industries successfully concluded discussions on a proposal which is expected to expedite development of seed orchards in the province. Under the proposal, the Forest Service may purchase and provide land to forest industries who in return will be obliged to bear all costs of establishing and operating seed orchards and provide the Forest Service with a portion of the seed crop required for its own use.

## ASSEMBLY OF BREEDING STOCK

The selection of superior trees to provide base material for selection and breeding projects continued with most of the efforts directed at white spruce in central and northwestern Alberta. A total of 83 white spruce and 40 lodgepole pine trees were selected. Cone and/or scion collections were made from the selected trees. Field work for most of this work was carried out by Procter and Gamble Cellulose, Simpson Timber Company, and the Alberta Forest Service.

## PROGENY TESTING

As part of genetic improvement of lodgepole pine in breeding region B1, four open pollinated half-sib family field trials were established jointly by the Alberta Forest Service, Procter and Gamble Cellulose, Canadian Forest Products, and British Columbia Forest Products. Region B1 contains 14 800 $km^2$ area covering parts of the Grande Prairie and Whitecourt Forests. The field trials were outplanted in the spring, 1981 using container stock produced from OP seedlots obtained from selected superior trees located mostly within the region. The field design consisted of blocks in reps layout (5 replications, 4 tree row plots) with 400 families grouped in 25 unique and independent sets of 16 families each.

Site treatment and development of four test sites for establishment of field trials as part of the genetic improvement of lodgepole pine in breeding region C was completed jointly by Simpson Timber Company, and the Alberta Forest Service. The planting stock for these trials is being produced by the Alberta Forest Service and outplanting will be done in spring, 1982.

Procter and Gamble Cellulose completed a field establishment of an experiment designed to estimate the difference in growth performance of open pollinated progeny of selected superior vs. randomly found lodgepole pine trees. Two field trials were established using planting stock produced from seedlots collected from 20 superior and 20 random trees selected from five local stands.

## SEED ORCHARDS

A 15 ha lodgepole pine seed orchard plantation was established in spring, 1980 in the Grande Prairie Forest jointly by Procter and

Gamble Cellulose and the Alberta Forest Service. Planting stock for this plantation was produced from a seedlot formed by bulking seed obtained from 201 selected superior trees. The planting was done at 3 m (between rows) X 1 m (within row) spacing and it will be progressively thinned to retain about 20 percent of the best trees for seed production. This plantation was primarily established to evaluate effectiveness of phenotypic mass selection as an alternate breeding scheme to provide relatively low cost seed that may be economical for use in direct seeding programs.

Procter and Gamble Cellulose began work to define the criteria to select a suitable seed orchard site within the Grande Prairie general area (440 km northwest of Edmonton) during 1980. Surveys of available agriculture land were made in order to locate a site with coarse textured soil, ready availability of water for irrigation and micro-climate that would aid in seed production of white spruce and lodgepole pine.

The Alberta Forest Service started the site development for a white spruce seed orchard to be located at Smoky Lake. Fencing of the site was completed and work started on the installation of an irrigation system.

The Alberta Forest Service and Procter and Gamble Cellulose initiated a co-operative study to monitor flowering and seed production response of white spruce grafts at several southern locations to identify the best climate for locating seed orchards of this species. One field trial was established in summer, 1981 at Brooks in southeastern Alberta. Two additional plantations, one each in central and northwestern Alberta, will be established in 1982. Each plantation contains 3 or 4 ramets each of 10-16 white spruce ortets originating from northern Alberta. One set of this material was established earlier by the British Columbia Forest Service in its clone bank at Vernon.

## SEED PRODUCTION AND SEED COLLECTION AREAS

No new seed production or seed collection areas were established in the province during the past two years. The Alberta Forest Service is currently reviewing its commitment and approach to this work. It is anticipated that work on locating and earmarking excellent quality stands as cone collection reserves will resume later this year and intensify in the following years. In the meantime, a study was started to develop and define methods, procedures, and criteria for objective evaluation of phenotypic quality of natural white spruce stands.

# GENETICS AND TREE IMPROVEMENT RESEARCH ALBERTA FOREST SERVICE, 1979-1981

J.M. Schilf, N.K. Dhir, and P. Flinn

*Reforestation and Reclamation Branch*
*Alberta Forest Service*
*Edmonton, Alberta*
*T5K 2C9*

Key Words: forest genetics, tree breeding, tree seed, provenance studies, species tests, seed production, genetic variability, white spruce, lodgepole pine, tamarack.

The genetics and tree improvement research program of the Alberta Forest Service is still in its early stages. The work is divided into four projects: species testing, provenance research, genetic studies, and seed production and related studies. This report describes the progress of work carried out over the past two years.

## SPECIES TESTING

Work on species testing was started in 1976 to evaluate the comparative performance of promising native and exotic tree species and to determine their suitability for forest regeneration in various regions of the province. Acquisition of seedlots for species testing research nears completion and field establishment of all experimental plantations required as part of this project is expected to be concluded in 1986.

A larch species trial using container seedling stock was established at Smoky Lake to test and compare field performance of tamarack (1 seedlot), Siberian (raivola) larch (1 seedlot), and Western larch (8 seedlots). At the end of nearly two growing seasons in the field, all seedlots showed excellent survival and the mean height of the three species was: tamarack 28 cm, Siberian larch 36 cm, Western larch 37 cm.

A field trial was established on a nutrient poor sandy soil site to monitor and compare field performance of white spruce, black spruce, lodgepole pine, tamarack, and white birch in pure and mixed planting with green alder (Alnus crispa). The experimental design consisted of replicated row plantings of the five species with and without alternating rows of green alder.

Greenhouse production of experimental planting stock was completed for field outplanting of two additional experiments:
1. A pine species test to compare performance of red pine, ponderosa pine,

lodgepole pine, and jack pine. Each species is represented by 1-7 seed sources.
2. A maple species trial (sugar maple, Japanese maple, and red maple) to determine the adaptability and winter hardiness of selected seedlots of these species for possible use in amenity or ornamental plantings in Alberta.

## PROVENANCE RESEARCH

As part of an extensive series of white spruce provenance trials to be established throughout the province, planting stock to provide materials for three additional field trials was transplanted in separate nursery experiments. Twelve similar experiments were earlier established in nursery transplant beds during 1976-1979. Field outplanting of these experiments started in the spring of 1980 using 4-year-old planting stock and the establishment of six field trials was completed by spring of 1981. One of the three field trials established in spring, 1980 in the foothills region of southern Alberta showed severe mortality (82%), with the exception of local seed sources and the seed sources originating from the foothills due north of the plantation region. The plantation failure was attributed to winter desication since the 1980-81 winter had an unusually low snowfall and frequent warm temperatures. The plantation site was replanted with surplus stock in spring, 1981.

Observations on flushing dates of the white spruce provenances established in the fifteen separate nursery experiments were started in 1979 and continued in 1980 and 1981. The experimental design permits evaluation of flushing dates relative to the geographic origin of 19 seed sources in three different years on seedlings of 3 different ages ( 1 year old, 2 year old, and 3 year old). Data from this study has been compiled and statistical analyses are expected to be completed later this year.

Outplanting of two scots pine seed source trials, consisting of 25 seed sources originating from above 50°N latitudes in the U.S.S.R. was completed in spring, 1980. One field plantation was established in central Alberta and the other in northern Alberta. Each of the plantations included a lodgepole pine seedlot for comparison purposes. These plantations are part of a co-operative study initiated by the U.S. Forest Service.

A ponderosa pine seed source trial established in the nursery in 1977 was outplanted as a field trial in central Alberta in 1980. It contains 14 seed sources of relatively high elevation origins from North Dakota, South Dakota, Montana, Wyoming, and Colorado. Evaluation of a Norway maple seed source trial established in the nursery in 1978 showed that none of the seedlots are winter hardy in a central Alberta test environment. This trial was part of a co-operative study initiated by the Petawawa National Forestry Institute and consisted of 12 single tree of bulk seedlots from three geographic origins from the U.S.S.R..

## GENETIC STUDIES

A study was started to evaluate genetic variability and correlations among open pollinated seedlots of 37 parent trees from a white spruce stand from which seed was collected in two different seed crop years. Data on seedling performance (height, shoot and root dry weights) was recorded in two greenhouse test environments and evaluation of the results is in progress. The remaining seedlings from this experiment will be outplanted in a field trial to be established in 1982.

A greenhouse study of genetic variability in 114 open pollinated families of lodgepole pine originating from 38 stands located in west-central Alberta was concluded. It was interesting to note that families/stands effects were significant for all traits (seed germination count, cotyledon number, seedling height, shoot and root dry weights, and shoot:root ratio), whereas stand effects were found to be significant only for seed germination count, cotyledon number, and shoot:root ratio. Additional data on seedling height was collected from another greenhouse study of 240 open pollinated families originating from 60 stands located in central Alberta. The data on greenhouse performance of lodgepole pine families is being accumulated for the purpose of calculating genotypic and phenotypic correlations with the later field performance of the same families in order to develop a possible criteria for screening poorer families based on greenhouse test results.

## SEED PRODUCTION AND RELATED STUDIES

A study on seed quality of seed collected in two different seed years from each of 37 seed trees from a seed production area was completed. Analysis of variance of seed germination data showed highly significant ($p \leq 0.01$) differences due to seed years, seed trees, and cold stratification treatments. All interactions among the main effects were also statistically significant. Overall mean germination percentages were as follows:

| | | |
|---|---|---|
| 1976: | $40 \pm 4$ (unstratified) | $86 \pm 2$ (stratified) |
| 1979: | $63 \pm 4$ (unstratified) | $98 \pm 1$ (stratified) |

Thousand seed weight (adjusted to 6% moisture content) of seed trees from seed crops of the two different years was not significantly correlated ($r=.24$). The mean germination percentage of the seedlots (unstratified seed) showed highly significant correlation between seed years ($r=.66$). However, it was interesting to note that mean germination of stratified seedlots showed extremely poor correlation ($r=.05$) between seed years. No relationship was found between seed weight and germination capacity of seedlots in either year.

Several reports in recent literature have reported successful induction of early flowering in white spruce and lodgepole pine by applying a continuous photoperiod and high levels of nutrients to the seedlings of these species while being grown in a greenhouse prior to outplanting. In light of this, a study was started in 1979 to evaluate

greenhouse response of white spruce and lodgepole pine to a continuous photoperiod and heavier application of nutrients, and to subsequently monitor flowering and seed production response of these materials in a field trial. Seedlings of both species were grown in a greenhouse under the prescribed (accelerated growth) environment for eight months. At the end of this period, the mean height of white spruce seedlings was 69 cm compared to 33 cm for lodgepole pine. Conventionally reared seedlings of the same seedlots of white spruce and lodgepole pine averaged 12.5 cm and 7.2 cm respectively. The substantial difference in height growth of white spruce and lodgepole pine under an accelerated growth environment for eight months is attributed to differing growth habits of the two species. White spruce showed continuous height growth throughout the eight months period, while lodgepole pine set bud after every 2-3 weeks of active height growth and stayed dormant for 2-4 weeks before flushing and resuming height growth.

At the end of the greenhouse study, seedlings produced under the accelerated growth environment were outplanted as a research plantation for future monitoring of growth, development, flowering, and seed production response of these. Conventionally reared seedlings were established as a control for comparing results.

## PLANT PROPAGATION AND SEED BANK

Apart from the production of planting stock for the Alberta Forest Service genetics and tree improvement research projects, plant propagation facilities of the Genetics Section, Alberta Forest Service are also responsible for the production of planting stock for co-operative genetic improvement projects with the forest industries of the province. During the report period, total production was 101,800 seedlings and 1,676 grafts.

An experimental study designed to develop a new growing schedule and nutrient prescription for greenhouse production of tamarack container stock was satisfactorily concluded. Several difficulties were being encountered earlier in growing tamarack seedling crop using a standard growing regime adopted for production of other conifer seedlings. Tamarack seedlings produced under this growing regime generally showed poor root growth, excessive lush top growth and spindly stems.

A total of 403 seedlot entries were added to the seed bank. The number of seedlots extracted and processed was 358. These represented open pollinated seedlots of selected trees and seed source stands, as well as general collections made for building inventory for experimental work and seed exchanges with other agencies.

Systematic germination testing of nearly 2,500 research seedlots in the seed bank was started and 321 germination tests were completed. It was decided that if sufficient seed can be spared, all seedlots will be germination tested at least once (as far as possible within the second or third month of their storage). For the purpose of monitoring seed quality in the long term, a set of 40 reference seedlots composed of

subsets of a varying number of seedlots of the major species in the seed bank, was selected for testing moisture content and germinability each year. This set will be progressively expanded every year to include a few more entries from the new seedlots being added to the seed bank.

A study was conducted on the effect of extended cone after-ripening of white spruce cones on seed yield and seed quality. Green cones nearing maturity were collected from 15 trees. Each of these collections were divided into two parts and separately air-dried at approximately $20^{\circ}/15^{\circ}$C day/night temperature for two and four weeks before being kilned and extracted. Both treatments were found to give similar seed yield, seed germination, and seed weight. As a result of this study, a standard two weeks air-drying period was adopted for drying white spruce cones before kilning and extraction.

# GENETIC IMPROVEMENT OF JACK PINE FOR THE PRAIRIE PROVINCES, 1979-81

J.I. Klein

*Northern Forest Research Centre*
*Canadian Forestry Service*
*Edmonton, Alberta*
*T6H 3S5*

Keywords: Pinus banksiana, family test, grafting, seed orchard, clone bank, progeny test

Height measurements at five years after planting are now on hand for all three family tests of the Northern Forest Research Centre's jack pine breeding program. These data have been used to a limited extent. Parent clones ranking near the top for their family test in progeny mean height, with reasonably favorable grafting records and scion producion, were selected and grafted for establishment of seed orchards by cooperators. There was some progress toward clone bank completion.

A draft manuscript for a comprehensive report on the jack pine breeding program has been reviewed, and is now being revised.

## CLONE BANK

A major share of program resources has been absorbed by clone bank development during the past two years. Stocking remains at about 60%, the same level reported in 1979 (Klein 1980 b). Grafts on hand in pots will, when planted, increase stocking to about 85%. Grafting success was achieved with some difficult clones by collecting scions in November or March and grafting in March on dormant understock. Clones which have yielded little or no grafting success were established in the clone bank by transplanting the primary ramets from a preliminary clone bank. I have intended to try late fall grafting for difficult clones, but have not yet been able to have understocks and time available then.

We are still refining the technique for rearing understocks. Watering and feeding by sub-irrigation during the container-rearing period resulted in straighter stems on the 1981 understocks, with much less staking and tying than was required for previous crops. Morphology of winter growth in the greenhouse has been unsatisfactory, despite manipulation of photoperiod and temperature. Now we will try storing the seedlings outdoors in their containers through the winter, then potting them up to complete their growth in a second summer.

## APPLICATION OF FAMILY TEST RESULTS

Cooperative grafting of progeny-tested clones was done for the western breeding district in 1979 (Klein 1980 b) and 1980, for the eastern breeding district in 1980, and for the central breeding district in 1981. Selection was based on progeny mean height superiority in each district's family test at five years from planting. Mean height of the progenies of selected clones was 8.5% and 7.2% above the test mean for the eastern and western district tests, respectively. Up to 300 scions of 26 clones have been grafted for one seed orchard. The resulting ramets were planted in a clone bank (Prince Albert Pulpwood Ltd.), lined out at a nursery to await development of an orchard site (Saskatchewan Forestry Branch), or planted in a seed orchard (Manitoba Forestry Branch). Ten-year results should support a more ambitious scale of application. Controlled mating of clone bank ramets will soon be practicable for high-ranking genotypes which are difficult to graft, and may prove to be the generally superior method for producing jack pine seed orchard trees.

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# FOREST GENETICS AT THE UNIVERSITY OF ALBERTA, 1979-81

Bruce P. Dancik

*Department of Forest Science*
*University of Alberta*
*Edmonton, Alberta*
*T6G 2G6*

Key Words: Isozymes, electrophoresis, population genetics, differentiation, mating systems, hybridization, polyploidy, leaf wax alkanes.

Forest genetics activities at The University of Alberta have focussed on the area of population genetics, utilizing starch-gel electrophoresis as the principle research technique. Over the past two years, several projects investigating jack and lodgepole pines, Douglas-fir, trembling aspen, white spruce, and birches have been completed or initiated.

## ENZYME VARIATION OF JACK AND LODGEPOLE PINE

Megagametophytes of 410 lodgepole pine (Pinus contorta var. latifolia (Dougl.) Engelm.), jack pine (P. banksiana Lamb.), and putative hybrids from ten Alberta populations were subjected to starch-gel electrophoresis. Twenty-one loci in 14 enzyme systems were scored to characterize allozyme variation of the taxa and clarify evolutionary relationships between the two species. Six loci exhibited high levels of heterozygosity (>45%) in at least one of the species. Differences in allozyme frequencies at eight loci permitted differentiation between the two parental taxa. Sixty-four percent of the loci in jack pine and 75% of the loci in lodgepole pine were polymorphic. Average heterozygosity of jack pine was .127, while that of lodgepole pine was .187. Jack pine had 2.07 alleles/locus, while lodgepole pine had 2.47 alleles/locus. Nei's genetic distance between the two species was .113. The reduced variability of jack pine could be the result of its evolution from a lodgepole pine-like ancestor after passage through a genetic bottleneck. Laboratory portions of this study were carried out while I was a visiting scientist at the Population Genetics Laboratory, B.C. Ministry of Forests. Francis Yeh and I are preparing a manuscript from this study.

## ENZYME VARIATION OF DOUGLAS-FIR

Megagametophytes of 99 Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco) from five foothill populations in Alberta were subjected to starch-gel electrophoresis. Twenty-six loci in 17 enzyme systems were scored to characterize allozyme variation within and among the populations. Eight loci exhibited high levels (>.45) of heterozygosity; average heterozygosity was .231. Alleles at five loci had frequencies markedly different

from those reported for B.C. populations. 67% of the loci were polymorphic. Genetic distances between Alberta and coastal B.C. populations were similar to those reported between other tree species.

Laboratory portion of this study were completed while I was a visiting scientist at the Population Genetics Laboratory, B.C. Ministry of Forests. Francis Yeh and I are preparing a manuscript from the results. A subsequent collection was made from four nearby populations in the Porcupine Hills to study local differentiation of enzyme loci. Results will be reported at the 17th IUFRO Congress at Kyoto, Japan, in October 1981.

## GENIC VARIATION OF TREMBLING ASPEN

Mr. William M. Cheliak completed his M.Sc. thesis on "Genic variation of trembling aspen in Alberta" in 1980. 256 clones in eight aspen populations in Alberta were studied to delineate variability in leaf morphology. Starch-gel electrophoresis was used to study crude enzyme extracts from dormant vegetative bud tissue from 222 clones in seven of these eight populations. The eight morphological characters and two derived ratio characters showed significant among-population variation. Discriminant analysis showed groupings of populations at similar latitudes. A total of 76 alleles coding for 26 putative loci were found in the populations studied. Average observed population heterozygosity was 0.52, with 2.3 alleles per locus and 85% of the loci polymorphic. A model was developed which indicated vegetative reproduction, with mutations accumulating by Muller's ratchet, could cause the high levels of variation maintained in the population. Within-population variation accounted for 94% of the total gene diversity.

Manuscripts reporting on this study are in various stages of preparation and review. This study was supported by a CFS Research Agreement within the Department of Forest Science and NSERC. Mr. John King and I are continuing this study with detailed investigation of individual clones to see if we can find evidence of somatic mutations within clones and "daughter" clones derived by mutation from other clones.

## LEAF WAX OF TREMBLING ASPEN

Mr. Barry C. Jaquish completed his M.Sc. thesis, "Natural variation in the leaf epicuticular wax alkanes and leaf wax morphology of trembling aspen (Populus tremuloides Michx.)". Gas-liquid chromatography was used to analyze the hydrocarbon fraction of leaf epicuticular waxes, and to describe the inter- and intraclonal, temporal, sexual and geographic variation in the hydrocarbons. The hydrocarbons were composed of seven normal-alkanes, with odd-numbered compounds predominating. Significant differences in alkane percentages existed among clones and crown strata, and between leaf types. Broad-sense heritabilities for all of the alkane characters except nC25 were high (>.60), indicating differences in the alkane characters are largely due to genetic differences among clones. The unique clonal alkane profiles indicated leaf wax alkanes have potential as clone delineators. All alkanes except nC23 and nC25 varied significantly over the growing season. The major transition in alkane concentrations occurred six weeks following leaf flush and may be related to the

cessation of surface wax deposition. Staminate clones contained significantly higher concentrations of nC23 and nC25, and lower concentrations of nC26 and nC27 than pistillate clones. Discriminant analysis correctly classified 83% of the clones to their appropriate sex. Scanning electron microscopy revealed pistillate wax is composed of dense, cruciform-shaped platey crystals which are oriented perpendicular to the leaf surface, while staminate waxes are less dense and are oriented horizontal to the leaf surface. This variability in wax morphology may give the selective advantage to pistillate clones in hotter environments and to staminate clones in cooler environments. Alkane concentrations were significantly correlated with elevation and average daily temperature. Significant differences among populations were found for all alkanes except nonocosane (nC29). Cluster and discriminant analyses of the alkane characters delineated two distinct groups of Alberta aspen.

This study was supported by a CFS Research Agreement.

## A NEW POLYPLOID BIRCH SPECIES

During a portion of my study leave, Burton V. Barnes and I completed a study of unusual birches, which we believe are octoploids (n=56) that arose from unreduced gametes of Betula x purpusii Schneider and reduced gametes of yellow birch (B. alleghaniensis Britton). Although polyploids account for 26% of temperate zone woody plants, we know of no other recent evidence of natural polyploidy. We are completing a manuscript describing and naming this birch and will submit it for publication shortly.

## NURSERY SELECTION OF LODGEPOLE PINE AND WHITE SPRUCE

With the cooperation of Dr. Narinder Dhir of the Alberta Forest Service we have been studying the genetic effects of nursery selection (for seed size) in lodgepole pine and white spruce (Picea glauca (Moench) Voss). Seed from unsorted and sorted seed lots of several populations has been subjected to starch-gel electrophoresis, and the isozymes scored. This study is being supported by the Dean's Agriculture Canada Grant.

## MATING SYSTEMS

Mr. Cheliak has been working on a Ph.D. study of the mating system and fitness selection components of jack pine. We expect the laboratory analysis of isozymes to be completed by the end of this summer (1981), with Mr. Cheliak writing his dissertation this fall and winter. Mr. King and I expect to start a study of the mating system and population structure of white spruce this fall. Preliminary work has been done on identifying isozyme loci and alleles and their inheritance. We are negotiating a contract with the Alberta Forest Service through Dr. N. Dhir to support this work.

## SPECIFIC GRAVITY AND FIBRE LENGTH VARIATION OF TREMBLING ASPEN

Mr. Alvin D. Yanchuk has begun an M.Sc. study of variation of wood

specific gravity and fibre length within and among clones of Populus tremuloides in central Alberta. This study is supported by a CFS Research Agreement with the Department and NSERC funds to Dr. M. Micko of the Department of Agricultural Engineering.

## NEW PERSONNEL

Ms. Hansi Klemm joined the population genetics (electrophoresis) laboratory as a Biological Technician in September, 1980; she has assumed the major responsibility for the day-to-day operation of the laboratory. Mr. James Lavoie joined the Department as a Biological Technologist in October, 1980; approximately 80% of his time has been spent in the population genetics laboratory. Dr. Francis C. Yeh, Technical Advisor - Genetics, Research Branch, B.C. Ministry of Forests, was appointed Associate Academic Staff member (Associate Professor) in 1980. Dr. Yeh serves on graduate student committees, presents occasional seminars and lectures, and provides advice to the genetics program.

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# TREE IMPROVEMENT IN SASKATCHEWAN

John D. Thompson

*Department of Tourism & Renewable Resources*
*Forestry Branch*
*Prince Albert, Saskatchewan*
*S6V 1B5*

Key Words: provenance tests, fertilization.

Tree improvement activities over the past two years have concentrated on: plus tree selection, planting of provenance tests, mass selection in nursery beds, fertilizing in the Maloneck seed production area, and grafting. White spruce (Picea glauca (Moench) Voss) has received the most attention. Provenance tests are planned for the exotic species of lodgepole pine (Pinus contorta var latifolia Engelm), red pine (Pinus resinosa Ait) and Scots pine (Pinus sylvestris L). A jack pine (Pinus banksiana Lamb) provincial provenance test was sown this spring (1981) and will be planted in the spring of 1982.

## WHITE SPRUCE

No plus trees were selected in 1980, 20 were selected in 1979 and grafted in the spring of 1980. The grafted material has been placed in a clone bank pending sufficient numbers of ortets to establish a clonal seed orchard.

Mass selected 3-0 and 2-2 seedlings are chosen each spring and fall for a seedling seed orchard.

The Maloneck plantation was established during the years 1939 to 1942. The plantation has been used for a seed production area since 1975. The seed obtained from this stand has germinated consistently above average (85% vs 70%); therefore, if by fertilizing, cone crops could be induced annually, the results would be very beneficial.

An experiment was set up with the assistance of the Northern Forest Research Centre to determine whether, with fertilizer applications, cone production could be augmented in good years and be maintained in poor seed years (Brace 1978). The experimental prescriptions involve different levels of nitrogen and phosphorous on one tenth acre (0.13 ha) plots.

The duration of the experiment is six to eight years. Annual cone counts on selected plot trees will determine whether the fertilizer applications have any effect on cone production.

## PROVENANCE TESTS

The range-wide white spruce provenance test was planted in three locations in the fall and spring of 1980, 1981 respectively. The design employed is the augmented randomized complete block design (Federer 1961). The provincial breakdown by sources is:

| | | | |
|---|---|---|---|
| Saskatchewan | 14 | Nova Scotia | 2 |
| Alberta | 14 | North West Territories | 1 |
| British Columbia | 12 | Ontario | 9 |
| Manitoba | 12 | Prince Edward Island | 2 |
| New Brunswick | 1 | Quebec | 6 |
| Newfoundland | 1 | Yukon | 2 |

Each plot has twenty-five (25) trees at two by two metre spacing with thirty-six (36) plots per block and four blocks per location.

The lodgepole pine provenance test is composed of sources from Alberta (9), British Columbia (17) and the Inland Empire Co-operative (12) from Montana, Idaho and Washington. This test will be planted at three different locations in 1982.

The red pine test will be out planted in 1983 at three locations across the province. Sources for this test are from Ontario (13), New Brunswick (1), Nova Scotia (1), Wisconsin (1) and Michigan (2).

The Scot's pine provenance test was planted this spring (1981) at a single location. This test has a total of seventy-one (71) provenances from European and Asian portions of the Soviet Union. Of these sources sixty-seven (67) are north of 50° latitude. The general geographic locations are:

| | |
|---|---|
| Murmansk, Karel and Arkhangel | 7 |
| North Central Russia | 6 |
| Western Russia | 6 |
| Central Russia | 7 |
| Eastern Russia | 6 |
| Southern Russia and Caucasus | 7 |
| Ural Mountains | 8 |
| East of Urals and Kazakh | 3 |
| Ob River and Altay Mtns. | 3 |
| Yenisey River | 6 |
| Angara River and L. Baykal | 6 |
| Chita, Amur, Khabarov, Yakutsk | 6 |

The sources were gathered by the U. S. Forest Service and distributed to various agencies including the Northern Forest Research Centre from which Saskatchewan received its stock. (Read 1978).

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# JACK PINE TREE IMPROVEMENT, PRINCE ALBERT PULPWOOD

D. Roddy

*Prince Albert Pulpwood*
*Prince Albert, Saskatchewan*
*S6V 5T3*

Major emphasis in Prince Albert Pulpwood's operations is being placed on silviculture and forest management. A jack pine (Pinus banksiana) tree improvement program to augment this was established in 1977 under the direction of Dr. Bruce Zobel. The direction of the program was outlined in a previous report (Orynik, 1979) and progress has been good. Our established 2-hectare clonal seed orchard, based on thirty very intensively selected trees, was expanded this year to 7.2 hectares through a large field grafting program. This orchard will be rogued on the basis of open and control pollinated trials. The first of the open pollinated trials will begin in the spring of 1982 with the control pollinated trials beginning after flower production starts.

One hundred less-intensively selected trees have also been chosen, and another one hundred will be picked by the fall of 1982. The progeny from these trees will be planted in the field trials over the next four years and the results of these tests will be used to establish a second seed orchard from which we will obtain seed of higher genetic quality than the present orchard. The first of these progeny trials was planted this spring in five replications on different sites throughout our lease area.

Wood specific gravity has been determined for the thirty intensively selected trees and will also be determined for the next one hundred less intensively selected trees we choose. Once the range of wood specific gravity is found for trees in Northern Saskatchewan, wood density will be used as a selection criterion. This will ensure against selecting trees which are fast growing but have a high water and air, rather than fibre, content.

A clone bank on the seed orchard site will be expanded this year so that it contains all the genetic material in the orchard and a second clone bank of this material will be established in 1982 at another location for insurance purposes.

In 1979 we received from the Canadian Forestry Service, several grafts of the twenty best families (based on 5-year measurements) of their jack pine progeny trials in Northern Saskatchewan. These have been established in our clone bank and will be incorporated into our program on the basis of the ten year progeny trial results.

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# TREE BREEDING AND EVALUATION - MORDEN RESEARCH STATION 1980-1981

W.G. Ronald

*Agriculture Canada, Research Station*
*Morden, Manitoba*
*R0G 1J0*

Key Words: native Canadian trees, prairie adapted provenances, Salix, Populus, Betula.

Several promising native tree sources were identified from among the more than 150 accessions received annually by the Morden Arboretum. A weeping willow, 'Prairie Cascade', was introduced in 1981 and selection work was continued to identify a hardier golden willow. Populus breeding emphasized the genetic basis of cutting rootability; selection was continued for this factor and for shelterbelt adaptability. Species susceptibility to birch borer damage was evaluated and several white barked selections were identified which possessed a degree of resistance.

## PRAIRIE ADAPTED PROVENANCES OF VALUABLE CANADIAN TREES

Available commercial sources of Fraxinus americana (white ash) have consistently failed to establish in the prairie region. New provenances obtained from northern Canadian sources (Petawawa, Ontario) and northern U.S. sources (Minnesota) have developed excellent specimens at Morden while nearby commercial sources failed during severe winters. The adapted sources will be distributed for shade tree production in prairie Canada.

Populus grandidentata (large toothed aspen) obtained from its north western continental distribution in south eastern Manitoba performs well at Morden. Female clones predominate in Manitoba but one male clone discovered in 1981 served as a pollen source for production of seed. Seed production may provide a commercial procedure for production of trees.

Acer rubrum (red maple) obtained from its north western continental distribution near Kenora, Ontario has proven the most adapted source for possible prairie production. The incidence of sunscald to tree trunks appears

to be the limiting factor to wider use of the red maple in prairie regions.

Quercus bicolor (swamp white oak) obtained in 1966 from Minnesota offers potential to extend the narrow range of oaks available for the prairie region.

## IMPROVEMENT OF SALIX

A breeding program with the objective of developing an adapted weeping willow for the prairie region has resulted in the release of the 'Prairie Cascade' cultivar in 1981. This new cultivar should enable reliable prairie production of weeping willows for the first time.

Crossing and selection work is continuing with the objective of developing a hardier replacement for the golden willow (Salix alba 'Vitellina').

## IMPROVEMENT OF POPULUS

P. x canescens 'Tower' a columnar hybrid introduced in 1979 from Morden has become widely accepted by commercial nursery growers. Studies have developed a reliable propagation procedure which uses 2 cm long root cuttings given a 2 week warm preconditioning in moist peat moss prior to planting in peat pots in the greenhouse in March or April. The small plants produced are then field planted in late May and result in a saleable 1 m plant by fall.

Studies of intersectional species hybrids were continued with objectives to recombine disease resistance, propagation ease and hardiness. The rootability of hardwood cuttings was found to have strong genetic control. Several selections were identified amongst these first generation intersectional hybrids.

Other advanced breeding lines include columnar silver poplars, columnar cottonwood hybrids and progenies of P. x jackii 'Northwest' with higher levels of disease resistance.

## SELECTION FOR BORER RESISTANCE IN BETULA

Birch borer and drought damage has caused widespread losses to prairie birch plantings particularly to European birch and its weeping cultivars. The native dark barked Betula occidentalis (syn. fontinalis), fountain birch, has been found to offer apparent resistance. This species is

cold and drought tolerant and although lacking in white exfoliating bark it has produced some such hybrid seedlings. Several white barked selections were increased by grafting and will be evaluated.

In addition to this native species the Asiatic Chinese paper birch (Betula albo sinensis septentrionalis) appears promising as a borer resistant species.

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# GENETICS OF GENECOLOGY OF SPRUCE, SAULT STE. MARIE, ONTARIO, 1979 AND 1980

Alan G. Gordon

*Central Forest Research Unit*
*Ontario Ministry of Natural Resources*
*Sault Ste. Marie, Ontario*
*P6A 5M7*

Keywords: Picea, genecology, genetic variation in spruce forest ecosystems, hybridization, Piceta

The program in genecology and genetics of spruce seeks to provide a broad scientific basis for tree improvement and to enhance our understanding of the structure and functioning of ecosystems and how this may be used for their best management.

The objectives are (1) to elucidate the contribution of species, forms, provenances and hybrids in productivity systems; (2) to collect and interpret information on genetic parameters particularly genotype x environment interaction, in regard to genecology and phylogeny of the genus Picea; and (3) to evaluate the effect of provenances, seed zones (site regions) in productivity systems, and confirm the validity of the limits of movement of spruce stock between regions, etc. as compared with local sources.

The program includes intra and interspecific hybridization studies, some range-wide provenance and local seed source studies and Piceta.

## HYBRIDIZATION

Breeding in 1979 was confined almost entirely to one area, Sault Ste. Marie. Twenty-two interspecific crosses with controls involving fifteen species of spruce were attempted using several clones. Some of these were repeat crosses, both to obtain repeatability estimates, and to increase stocks of particular hybrid clones. Picea omorika clones as female parents were crossed with different pollen sources of P. omorika, P. glauca, P. engelmannii, P. sitchensis, P. chihuahuana, P. koyamai, P. orientalis, P. pungens, P. abies, P. schrenkiana, P. asperata, P. breweriana, P. likiangensis, and P. maximowiczii. Clones of P. rubens as female parents were crossed with P. rubens, P. glauca, P. engelmannii, P. pungens, P. sitchensis, P. chihuahuana, P. orientalis, P. breweriana and P. mexicana. P. mexicana was crossed with P. glauca. In addition, hybrid P. rubens x P. omorika was crossed with local pollen sources of P. glauca, P. mariana and P. rubens.

Of the foregoing, P. omorika x P. pungens, P. abies, P. schrenkiana, P. asperata and P. breweriana were failures with all clones and pollen sources. It is noteworthy that the first three have been consistent failures over several years. P. rubens x P. engelmannii, P. pungens, P. chihuahuana,

P. orientalis, P. breweriana and P. mexicana were also failures with all clones and pollen sources, as also was P. mexicana x P. glauca. However, P. omorika x P. glauca, an older cross (Jeffers 1971), and P. omorika x P. sitchensis (Eklundh 1943), as well as P. omorika x P. engelmannii, previously reported (Gordon 1975a), provided good repeatability data, as did P. omorika x P. chihuahuana (Gordon 1976a). Crossability of the latter remains very low, but consistent.

Repeatability was achieved with P. rubens x P. glauca (Gordon 1978; cf. Bongarten and Hanover in press), and P. sitchensis (Gordon 1978). Crossability, as expected, was extremely low.

For the first time, limited success (not from all clones) was achieved with P. omorika x P. koyamai and P. omorika x P. orientalis. Crossability was very low, and slightly better with P. orientalis. The putative hybrid seedlings exhibit hybrid characteristics. Both these crosses were first reported by Wright (1955) but the progenies were subsequently invalidated (Santamour 1967).

Two other new crosses were P. omorika x P. maximowiczii, a very uncommon Japanese species and P. likiangensis, a Chinese species of limited distribution. The crossability using P. maximowiczii was extremely low and the progeny still unconfirmed. However with P. likiangensis it was 50 to 100%, matching the unusually high and useful crossability of P. omorika x P. rubens and P. omorika x P. mariana (Gordon 1975b, 1976b; Fowler 1980). Progeny of the P. omorika x P. likiangensis cross have been confirmed.

In 1980 breeding was conducted over a latitudinal range in Ontario from Sault Ste. Marie and Algonquin Districts to Simcoe District in the south. Thirty-five interspecific crosses representing fifteen species of spruce were attempted. Eighteen interspecific crosses were successful. Some crosses were repeats to obtain repeatability estimates as well as to increase clonal stocks. Others were new.

Female parents were clones of P. orientalis, P. omorika, P. rubens, P. mariana, P. mexicana, P. sitchensis and P. X lutzii (P. sitchensis x P. glauca). Male parents were P. orientalis, P. rubens, P. mariana, P. sitchensis, P. glauca, P. pungens, P. likiangensis, P. koyamai, P. maximowiczii, P. asperata and P. abies. It was not necessary to attempt all possible combinations.

The least responsive clones were of P. mariana, crossing successfully only with other P. mariana, as well as one doubtful cross with P. asperata. Disappointingly, P. mariana when crossed with P. sitchensis, was also unsuccessful. Fowler et al. (1980) reported this as a new cross going back at least to 1978. Crosses in the reciprocal direction, however, were successful for the first time. P. sitchensis as the female parent crossed with Ontario P. mariana. Crossability was low, but the small number of confirmed hybrid seedlings are distinctly heterotic. P. sitchensis, of course, also crossed easily again with P. glauca. P. sitchensis x P. likiangensis as a new cross was first accomplished by workers in Britain in 1970 (Faulkner 1971). This cross was repeated successfully. Crossability is very low and the seedlings are interesting but do not appear to be heterotic.

P. sitchensis x P. rubens first reported in this direction in 1978 (Gordon 1980) were unsuccessful in the 1980 season. The reciprocal, P. rubens x P. sitchensis, however, a new cross in 1976 (Gordon 1978) was

successfully repeated with new clones and different pollen parents. The seedlings produced in 1976 have been confirmed and are very promising.

P. X lutzii was crossed successfully with P. rubens. The seedlings however are abnormal. P. sitchensis failed as usual with P. abies and also with P. maximowiczii.

P. omorika x P. asperata, P. orientalis, P. koyamai and P. maximowiczii appear successful but the seedlings await confirmation.

As yet, unconfirmed crosses occurred with P. rubens x P. koyamai, and P. asperata (both doubtful), P. sitchensis and P. glauca. Confirmed successes were with P. rubens x P. orientalis, P. maximowiczii (new) and P. likiangensis (new). Although we first successfully made the cross P. rubens x P. orientalis in 1974, we have had little success repeating it. Fowler (1969) reporting on work of Holst, and Jeffers (1971) reported this cross with little comment. The progeny of the present cross are very vigorous regardless of parental provenance. Crossability was moderate, varying from less than 1% to about 6% and similar to that of P. rubens x P. likiangensis.

P. mexicana was crossed successfully with P. rubens, repeat cross (Gordon 1980); and, utilizing different parents, with P. glauca with much greater crossability than was previously noted (Gordon 1980). A new and unexpected cross was P. mexicana x P. likiangensis. Crossability was moderate and all progeny were confirmed. P. mexicana failed to cross with P. mariana.

## PRODUCTION AND APPLICATION OF INTERSPECIFIC HYBRIDS

Data illustrating eight years of development of P. omorika x P. rubens hybrids, reciprocals and controls was presented to the Canada-Ontario Joint Forestry Research Committee (COJFRC), Information Session for Forest Managers, February 1979, as an example of interspecific breeding contributing to tree improvement.

Other work of this program consists of flower induction studies, rooting techniques used for rapid multiplication of hybrid stock, and genotype x environment, etc. studies in our Piceta.

The work of this Unit is otherwise largely occupied with productivity and nutrient cycling studies in spruce forest eocsystem research (Gordon 1979; Blum et al. 1980, etc. ibid 1980).

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# RESEARCH ON SEED-CONE RECEPTIVITY, SEED PRODUCTION POTENTIAL, CONE INDUCTION AND HAPLOID PLANT CULTURE

Rong H. Ho

*Ontario Forest Research Centre*
*Ontario Ministry of Natural Resources*
*Maple, Ontario*
*L0J 1E0*

Key Words: Picea glauca, Picea mariana, Populus species

The studies on seed-cone receptivity and seed production potential, and cone induction were initiated in the spring of 1980 and encompassed white (Picea glauca /Moench/ Voss) and black spruces (P. mariana /Mill./ B.S.P.). The objectives were (1) to determine the optimal time for controlled pollination, (2) to define the seed production potential per cone, and (3) to induce cone production.

Research on haploid plant culture and vegetative propagation in vitro started in April, 1981, after the setup of a biotechnology laboratory. The objectives were to produce poplar (Populus L. spp.) and white spruce haploids, and clone a specific genotype through in vitro technique. Dr. Y. Raj[1] is associated with the study and the poplar material was supplied by Dr. L. Zsuffa[1].

## SEED-CONE RECEPTIVITY

In white spruce, the proximal end of a seed cone emerged from the bud scales and was the area to be receptive first. Receptivity of a seed cone lasted for about 10 days. The end of receptivity was signalled by the enclosure of cone scales. Optimal receptivity occurred when seed cones approached the end of receptivity and this coincided with the peak of pollen shedding. It was evident that seed cones, pollinated once at this stage, produced the most filled seed, on the average of 41.6 per cone.

## SEED PRODUCTION POTENTIAL

Total cone scales in white spruce averaged 67.8 per cone. The fertile scales consisted of 43.6 per cone and the sterile scales 24 per cone. The sterile scales were located at the proximal and distal ends of a cone, and the distal end had more sterile scales (12.8) than the proximal end (11.3). The seed production potential was 88 seeds per cone.

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[1] Geneticist, Ontario Forest Research Centre, Ontario Ministry of Natural Resources, Maple, Ontario L0J 1E0.

In black spruce, total cone scales averaged 57.8 per cone of which 27.2 scales were fertile and 30.5 scales were sterile. The fertile cone scales located at the mid-portion of a cone. There were more sterile cone scales at the proximal end (18.6) than at the distal end of a cone (11.9). The seed production potential averaged 54 seeds per cone.

## CONE INDUCTION

Two studies were carried out in cone induction. In one study, gibberellic acid (GA) 4/7/9 (100 micrograms/week) was applied to white and black spruces for 2 to 8 weeks. In the other study, white spruce trees were girdled, root-pruned or both.

GA is effective in inducing pollen and seed cones. In white spruce, GA increased the average seed-cone production by 6-fold and the average pollen-cone production by 2-fold after an 8-week treatment. The increase in black spruce was 4-fold in seed-cone production and 10-fold in pollen-cone production. Clones responded differently to GA treatments. Pollen viability and tree height growth were not affected by the treatment.

Root pruning appeared to be better than girdling in increasing cone production. Root pruning resulted in 5-fold increase in seed cones and 1.5-fold in pollen cones over the controls. The response was highly variable by clone. A combination of girdling and root pruning was not effective and the treated trees produced about the same amount of cones as the controls. The treated trees grew more in height than the controls.

## HAPLOID PLANT CULTURE

In poplar, anthers were incubated on a Murashige and Skoog (MS) medium (1962) containing 2 mg/l of 2,4-D, 2 mg/l of Kinetin, 3% of sucrose and 0.8% of agar when young pollen grains in the anthers were at the mononucleate stage and prior to the mitotic division (Zhu et al, 1980). After about 40 days of incubation, haploid calli have been obtained from pollen grains of 7 clones, i.e., P. angulata x simonii, P. x euramericana cv. bachelierii, P. x euramericana cv. eugenei, P. x euramericana cv. vernirubens, P. generosa x jackii, P. jackii (P. tacamahaca x deltoides), P. maximowiczii x deltoides. Diploid calli from the somatic tissues of anthers were produced from other species and hybrids. The haploid calli will be transferred to a new medium containing .2 mg/l of BAP (benzylaminopurine) and .2 mg/l of NAA for organogenesis.

In white spruce, microsporophylls were incubated on the medium as used for callus induction in poplar. After a month's incubation, only diploid calli were produced from the microsporophylls. The calli have been transferred to a new medium for organ induction.

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# SPRUCE AND LARCH GENETICS, ONTARIO FOREST RESEARCH CENTRE, 1979-80

J.V. Hood
Research Scientist

*Ontario Forest Research Centre*
*Maple, Ontario*
*LOJ 1E0*

Key Words: exotics, hybridization, selection and breeding

The spruce and larch program in Ontario has undergone personnel and organizational changes since the previous report (Rauter 1979) submitted to this Association. In April, 1979, R.M. Rauter transferred from the Ontario Forest Research Centre (OFRC), Maple, to the Forest Resources Branch, Program Development and Control Section, in head office, Toronto. From April, 1979, to June, 1980, projects initiated by Rauter were carried out under her guidance by K. Eng, now Tree Improvement Specialist, Central Region. Additional assistance was provided by D. Boufford, who also looked after the project during the remainder of 1980. I joined the OFRC staff as the spruce and larch geneticist in January, 1981.

## SPRUCE

### Interspecific hybridization

No hybrid crosses were attempted during the 1979 and 1980 breeding season. Field tests of earlier hybrid crosses are due for evaluation in the fall of 1981. Two hybrids that suggest some potential for southern Ontario are Picea glauca (Moench) Voss x P. sitchensis (Bong.) Carr and P. abies (L.) Karst. x P. Koyamii Shir. With these two exceptions, the spruce hybridization work at OFRC will be phased out to concentrate on selection and breeding of native spruces.

### Selection and breeding

In both 1979 and 1980 the controlled crossing program was continued in the black and white spruce clonal seed orchards near Angus. Black spruce pollen was collected from the Mattawin seed orchard and used, along with fresh pollen, for controlled pollinations in 1980. The 1980 white spruce flower crop at Mattawin was heavily damaged by late frost, as it had been the previous two years. The resulting seed from these crosses will be used to progeny test the clones in the orchards.

Open-pollinated progeny tests of black spruce plus trees from both the 3E and 3W site regions (Hills 1960) were planted during the 1979-1980 period, as well as an open-pollinated test of the McAcree 3W black spruce seed production area. An open-pollinated test of the O'Connor 4W white spruce seed production area was planted in 1980 on two sites. Clonal tests of both the black and white spruce seed production areas at Limestone Lake were planted in 1980.

## LARCH

### Exotics and interspecific hybridization

An interspecific crossing program has not been started at OFRC. However, since several hybrids have indicated some promise for short rotation forestry in Ontario (Calvert and Rauter 1979), trials have been initiated with hybrid seed obtained from a number of contributors. In 1980, a combined species and hybrid trial was planted at two sites in southeastern Ontario. The species represented were: Larix decidua Mill., L. dahurica Turcz., L. laricina (DuRoi) K. Koch. x L. decidua, L. gmelini (Rupr.) Litvin., L. decidua x L. kurilensis Mayr., L. decidua x L. leptolepis (Sieb. and Zucc.) Gord. and the reciprocal cross, L. laricina x L. decidua. A species trial of L. occidentalis Nutt., L. Leptolepis and L. decidua was planted at four southeastern locations in 1979.

### Selection and breeding

Stand trials of three different L. laricina collections were planted near Thunder Bay and at several locations in southeastern Ontario. Early survival in these plantations and the above hybrid trials was generally good, although a few plantations suffered from man-caused mortality. As with the spruces, I anticipate that the major thrust in the future will be on selection and breeding within the native populations of L. laricina.

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# DEVELOPMENT OF AN OPERATIONAL TREE IMPROVEMENT PROGRAM IN THE NORTHERN REGION OF ONTARIO

L.K. Miller

*Ministry of Natural Resources*
*Northern Region*
*60 Wilson Avenue*
*Timmins, Ontario*
*P4N 2S7*

Key Words: black spruce, jack pine, white spruce, seed collection and production areas, field grafting, fertilization and subsoiling, clonal testing.

Under the auspices of the Department of Regional Economic Expansion (DREE), L.K. Miller was hired as the Regional Tree Improvement Specialist for the Northern Region, Ministry of Natural Resources in October, 1981, to coordinate the tree improvement efforts in the region. A considerable amount of time was spent becoming familiar with the organization, personnel, and existing tree improvement activities throughout the region. At the present time, operational tree improvement programs have been drafted for black spruce (Picea mariana (Mill.) B.S.P.), jack pine (Pinus banksiana Lamb.), and white spruce (Picea glauca (Moench.) Voss.). The author has also assisted field staff in seed collection and seed production area establishment and management, initiated small applied research projects, cooperated with research staff in black spruce clonal tests, and provided technical assistance as requested.

## A. TREE IMPROVEMENT PROGRAMS

Based on existing tree improvement programs and expected demand for seed in the regeneration program, draft proposals for future tree improvement strategies in black spruce, jack pine, and white spruce have been written. These plans have been presented to each district, and finalized versions will be written incorporating appropriate changes or modifications. As soon as each long term plan is approved, operational tree improvement can commence.

## B. SEED COLLECTION AND PRODUCTION AREAS

At this writing, a new black spruce SPA has been extablished in Cochrane District, a new black spruce SCA has been proposed in Hearst District, and a new jack pine SCA has been proposed in Chapleau District.

## C. APPLIED RESEARCH STUDIES

### 1. Field grafting

With the cooperation and assistance of the Kirkland Lake District staff, a jack pine field grafting study was initiated in late May, 1981. This study is designed to test the success and performance of the field grafting procedure in jack pine.

In early June, 1981, field grafts of black and white spruce were made at the Bonner Tree Improvement Center, Moonbeam, Ontario. The objective of this study is to improve the success and performance of spruce grafting.

### 2. Fertilization and subsoiling

In an effort to apply proven methods of flower promotion developed in other species to black and white spruce, a study investigating the effects of ammonium nitrate fertilization and subsoiling was initiated in mid-June, 1981. Two levels of fertilizer and two depths of subsoiling were applied singly and in combination to stands of black spruce (aged 12-20 years) and white spruce (aged 14-20 years).

## D. BLACK SPRUCE CLONAL TESTS

In cooperation with the Ontario Forest Research Center, Maple, a black spruce clonal test will be outplanted in the Northern Region in the spring of 1982. The planting stock will be rooted cuttings taken from control pollinated families of plus trees selected from the Northern Region. Clonal testing offers several advantages over traditional progeny testing. There is no need to accumulate large quantities of control pollinated seed. Additionally, clonal tests allow estimation of non-additive variance components, and do not require large plots and many replications.

# AN OVERVIEW OF THE PROVINCIAL TREE IMPROVEMENT PROGRAM IN ONTARIO

R. Marie Rauter
Silviculturist

*Tree Seed and Forest Genetics*
*Ministry of Natural Resources*
*Toronto, Ontario*

Key Words: strategies, staffing, facilities, regional programs, support programs.

One of the primary objectives of the tree improvement program in Ontario is to establish improvement strategies for our major commercial species according to seed zone and seed need. Although some of the programs have been underway for several years, advances in breeding knowledge, changes in technology and changes in anticipated seed requirements have necessitated modifications to some of the earlier strategies.

The growing awareness of the need to produce genetically improved seed has resulted in improved funding, staffing and facilities. Since the beginning of 1979, the number of regional programs and support programs has increased substantially.

This paper will highlight some of the changes and the current status of tree improvement in the Province.

## TREE IMPROVEMENT STRATEGIES

Tree improvement strategies have been developed for white spruce (Picea glauca (Moench) Voss), black spruce (P. mariana (Mill.) B.S.P.), jack pine (Pinus banksiana Lamb.) and white pine (P. strobus L.). The size of each program is based on such factors as the projected seed need for a seed zone, seed periodicity of the species and seed yield per tree at various ages and under different management systems. Strategies are being developed for other species such as black walnut (Juglans nigra L.), white ash (Fraxinus americana L.), tamarack (Larix laricina (Du Roi) K. Koch.), European larch (L. decidua Mill.) and Japanese larch (L. leptolepis (Sieb. and Zucc.) Gord.).

More seed collection and seed production areas are being established in order to provide larger quantities of seed from controlled sources. These areas will provide large quantities of seed until the seed orchards come into production. Depending upon the characteristics of a species, either clonal or seedling seed orchards are being developed.

Some decisions have been made on mating designs and test procedures to evaluate the seed orchard material, but further discussions are still required with Ministry research staff.

## STAFFING

The number of individuals specifically assigned to work in tree improvement has increased since the beginning of 1979. In the present organization, the provincial tree improvement and tree seed program is co-ordinated by one silviculturist and supported by a forester and a part-time clerk. Prior to July 1980 there was only one field tree improvement specialist in the Province with the responsibility of covering the 4 northern regions. In July 1980, a second field position was created to cover the 4 southern regions and in October 1980 a third specialist was hired by one of the northern regions to hasten the implementation of its' tree improvement program. These field specialists provide the much needed guidance and support to the field staff and are able to co-ordinate many of the programs at both a Regional and District level.

Due to the shortage of trained tree improvement personnel in Ontario, a 2-year training position was established in 1980 under the direction of Head Office. Training is provided by research staff at the Ontario Forest Research Centre and by some of the field specialists.

In a related program, the Ministry hired a vegetative propagation specialist who is responsible for determining how to manage cutting donors to obtain maximum numbers of cuttings and to retain juvenility of the donor, for determining the best technology for rooting and for mass propagating selections for testing and production.

## FACILITIES

Grafting facilities have improved, but are still insufficient to meet the needs of the improvement program. Up to 1979, there were only 2 grafting centres in the Province, but a third and fourth were established in 1979 and 1980 respectively. These 2 new facilities have doubled the annual grafting capacity of the program from approximately 12,000 grafts to 25,000 grafts. Within the next two years, 2 more nurseries should have grafting facilities that will further increase annual production capacity to 40,000 grafts and this will be sufficient to provide the required material for the establishment of clonal seed orchards.

A large greenhouse expansion project is currently underway within the Province in order to accommodate the needs of the container stock production program. One nursery has already provided space in their new complex to grow seedlings for the seedling seed orchard program. As seed is collected from superior tree selections and as the greenhouses are completed throughout the Province, it is expected that additional space will be available as required.

Space has been reserved at several nurseries for the planting of clone banks and breeding orchards, as the nurseries have access to the manpower and equipment necessary for the intensive management of these areas. Additional scions for clonal expansion of the production orchard will therefore be of better quality, more numerous and available in a shorter period of time. Anticipated earlier flower production in these areas will also allow the breeding program to progress more quickly.

## REGIONAL PROGRAMS

Regional tree improvement programs have been underway for many years but these are presently very small and insufficient to meet the seed requirements of artificial regeneration programs. Most of their emphasis is in the selection and development of seed collection and seed production areas and in selection of plus trees for seed orchard establishment. In recent years the Regions have increased their emphasis on tree improvement with initiation of new programs and enlargement of established programs. A brief summary of work underway in the eight Regions follows.

### Northwestern Region

Tree improvement work in this Region is centred around black and white spruce. For the past several years, plus trees have been selected and scions grafted for clonal orchard establishment for both of these species. In 1979, the Region established its own grafting centre with an annual capacity of approximately 5000 grafts. Selections of white spruce will continue to be grafted until the clonal orchards are large enough to ultimately produce the projected seed requirements. Black spruce grafting and clonal orchard establishment have presently been discontinued in favour of seedling seed orchard development.

The Region embarked on an ambitious program for black spruce in 1978 with the selection of approximately 3500 plus trees within the seed zone for each Administrative District. Cones were collected in 1978 and 1979 and the seed extracted by individual seed lots and in the spring of 1980, several hundred seeds per lot were sown in its greenhouse complex and later transplanted to the nursery in the fall of 1980. The material will be field planted in the spring of 1982 to establish seedling seed orchards and simultaneous progeny trials on sites previously selected in all Districts within the Region.

### Northcentral Region

The emphasis in this Region is also on black and white spruce. Plus trees have been selected in both of these species for many years and several clonal orchards have been established and some of these have started to produce small quantities of seed. With the establishment of a grafting centre in the Northwestern Region the grafting facility in the Northcentral Region can now accommodate more of its own material and their plus tree selection targets were increased accordingly.

Northern Region

The Northern Region has detailed improvement strategies prepared in draft form for white spruce, black spruce and jack pine. These strategies summarize the rationale for the approach for a species, work done to date, future work as well as some proposed time frames. These outlines will form the basis for annual work plans and budgeting schedules for the individual districts within the Region. All seed collection areas and seed production areas are being evaluated and recommendations are forthcoming for their future management. The Orono nursery located in the Central Region has recently developed grafting facilities which presently accommodate the Northern Region's program. This allows for increased emphasis on the selection of plus trees for both black and white spruce as well as a regrafting program of earlier selections to increase the size and number of clonal production orchards already established for this Region. A 10-year management and operating plan is in preparation for the Bonner Tree Improvement Centre, where several of the proposed seed orchards for the Region will be developed.

Northeastern Region

This Region is in the process of developing tree improvement strategies for its major species. Major emphasis to date has been on the selection of plus trees of white pine and white spruce. In 1980 a selection program for superior jack pine was initiated and seed collected on an individual tree basis similar to the black spruce program in the Northwestern Region. When a sufficient number of selections have been made, the material will be used for the establishment of seedling seed orchards and progeny trials.

Algonquin Region

A tree improvement strategy has been developed for this Region's most important species, white pine. Nearly 200 plus tree selections have already been made and clonal orchards are being established. A regrafting program to increase the number of ramets per clone will be getting underway to enlarge the orchards to their desired size. White spruce is another important species for this Region and will receive additional emphasis now that the white pine program is well underway.

Eastern Region

The major improvement program in the Eastern Region is the poplar program. Some of the work includes propagating select clones provided by Dr. Zsuffa of the Ontario Forest Research Centre, establishing clonal trials under various management systems and on different sites, plus tree selection of the native poplar species throughout the Region and propagation of these plus trees both vegetatively and sexually.

As well the Eastern Region is currently evaluating all of their seed collection areas, seed production areas and seed orchards. Based on these evaluations and the projected seed requirements for the Region, tree

improvement strategies will be prepared for the other important species of this Region. Improvement programs are underway for white spruce, white pine, tamarack, European and Japanese larch. In 1980 the first material for the establishment of a European x Japanese hybrid larch orchard was planted.

Central Region

A white pine tree improvement strategy has been prepared for this Region and in 1980 the number of plus trees selected and grafted was substantially increased in order to accelerate the development of their white pine orchards. Greater emphasis has also been placed on the establishment and management of seed production areas for both white pine and white spruce. This Region is also participating in a black walnut improvement program and is actively seeking a suitable site for the development of black walnut orchards.

Southwestern Region

Most of the valuable species in this Region are hardwoods and most of their effort is in stand management rather than tree improvement. There is a program to select superior black walnut trees and to propagate these selections through grafts and by seed. White pine is also a commercially important species in this Region and efforts have increased in the selection of superior trees for the development of clonal seed orchards.

## SUPPORT PROGRAMS

In order to provide answers that are needed in planning and developing our major tree improvement programs and to provide information that will assist the field staff in understanding and carrying out the work programs, many short-term support projects have been initiated and funded by the Forest Resources Branch of the Ministry. Although some of the projects are under the direct supervision of the Tree Improvement Silviculturist or one of the Regional Tree Improvement Specialists, most of these projects are carried out by research scientists and support staff at the Ontario Forest Research Centre, Petawawa National Forestry Institute and the Faculty of Forestry at the University of Toronto as well as by private consultants. A list of some of these projects follows.

1) Identification, selection and evaluation of black walnut and white ash throughout their range in Ontario. Preparation of a tree improvement strategy for these species.

2) Identification of remnant stands of white spruce throughout southern Ontario. Collect seed and/or scions to retain the gene pool of the important populations. Preparation of a tree improvement strategy based on the material available.

3) Determination of cone and seed yields of black spruce on current, 1-year-old, and 2- to 4-year-old cones for various stand age classes throughout the northern part of the Province.

4) Mapping of soils in all seed orchards and proposed seed orchard sites throughout the Province.

5) Determination of variation in wood quality of tamarack.

6) Development of policy statements on establishment and management of seed collection areas, seed production areas and seed orchards.

7) Publication on the cone initiation and seed development of jack pine.

8) Publication of a seed collection manual that includes information from collection procedures to cone, fruit and seed yields by species.

## SUMMARY STATEMENT

Field staff as well as senior managerial staff are becoming increasingly aware of the benefits that can be derived from tree improvement. The annual increase in program and budget requirements is indicative of the increased efforts in this field. The many programs that are underway and those being developed will ultimately provide the genetically improved seed that is required for our artificial regeneration program.

# WHITE SPRUCE GENE POOL PRESERVATION IN SOUTHERN ONTARIO

W. vanBorrendam

*Ontario Forest Research Centre*
*Ontario Ministry of Natural Resources*
*Maple, Ontario*
*L0J 1E0*

Keywords: Picea glauca, provenance tests, selection.

A survey was initiated in 1980 to identify remnant populations of white spruce (Picea glauca (Moench) Voss) in southern Ontario. The project is the result of past provenance trials which indicated the probability of fast growing populations of white spruce in southern Ontario, with the famous Beachburg source being one example (Teich et al. 1975). The survey will form the basis of a subsequent research program to group sources of similar growth potential and evaluate differences in terms of collection and distribution policy in southern Ontario. Plantations will be established to preserve this gene pool and the selection of plus trees for site region 6E (Hills 1960) seed orchards will be based on this survey.

## WHITE SPRUCE

Past provenance trials indicate potential gains in rate of growth of between 10 and 20% after twenty years growth through the selective use of seed sources. It is apparent that even within site regions, the differences are well worth exploiting. This is particularly important in southern Ontario where only residual stands and scattered trees remain from some of the apparently fast growing southern sources.

Two valuable southern Ontario populations were identified in the Lake States and in trials across eastern Canada (Nienstaedt and Teich 1972). Beachburg and Peterborough sources exceeded the experimental mean heights by up to 40% in a wide range in test sites. Ensuring future seed supply from fast growing populations will improve the potential productivity of the over four hundred hectares of white spruce plantations established across site region 6E annually.

Inventory maps and reports will be prepared for each of the four administrative regions in southern Ontario, based on population groupings. A plan of plantation establishment will be prepared to preserve promising sources, to test relative potential growth of different sources and to provide for future seed collection of these sources. Plus tree selections will be made from promising sources within each population to establish seed orchards.

The methodology for surveying white spruce has been set up and ground and aerial surveying for the Central Region has been carried out. A report on existing white spruce gene pools in this region is presently being completed.

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# BREEDING OF FAST GROWING HARDWOODS AND WHITE PINES AT ONTARIO FOREST RESEARCH CENTRE, MAPLE, AND FOREST GENETICS AND TREE BREEDING AT THE FACULTY OF FORESTRY, UNIVERSITY OF TORONTO

Louis Zsuffa

*Ontario Forest Research Centre*
*Ontario Ministry of Natural Resources*
*Maple, Ontario*
*L0J 1E0*

Key Words: Poplar breeding, white pine breeding, willow breeding, alder breeding.

Poplar and white pine breeding programs have been active at Maple since mid 1940's. Recently, in addition to poplar, willow and alder breeding has started for biomass production in short rotations. In this report, the work and accomplishments in the period from 1979 to 1981 are summarized.

Since 1980, the author has offered courses in genetics at undergraduate and graduate levels. The initial activities at the Faculty of Forestry, University of Toronto are summarized in this report.

## POPLAR BREEDING

Work continued as outlined in the progress report for 1977 and 1978 (Zsuffa, 1980). Population studies, gene-pool collections and selections in trembling aspen (P. tremuloides Michx.) and balsam poplar (P. balsamifera L.) were started, and studies into resistance of poplar clones to diseases and insects were initiated. Karyotype studies in Populus were re-activated.

### Studies in Native Poplar Species

In eastern cottonwood (P. deltoides Marsh), the identification of the species-range in Ontario and the selection of representative female-tree specimens have almost been concluded. The analysis and propagation of this material is in progress. To date, 37 selections were made, 12 propagated by cuttings and 27 propagated by half-sibs.

In trembling aspen and balsam poplar, genetic variation studies and collections were initiated in cooperation and under contract with Dr. J. Eckenwalder[1]. The collections are being made (in 1981) according to Hills' site districts. Several sites are sampled within each district and five trees selected from each site. Seeds and vegetative propagules are collected, as well as data to allow taxonomic and genetic evaluations.

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[1] Department of Botany, University of Toronto

Pollination

In early 1980, the following crosses were made:

| Parentage (female x male) | No. of Combinations |
|---|---|
| P. deltoides x nigra L. | 4 |
| P. deltoides x Maximowiczii Henry | 3 |
| P. grandidentata Michx x alba L. | 1 |
| P. grandidentata x canescens (Act) Sm | 7 |
| P. tremuloides x tremula L. | 1 |

Thirteen hybrid progenies were produced from the 20 crosses made.

In early 1981, the following crosses were attempted:

| | |
|---|---|
| P. alba x grandidentata | 2 |
| P. alba x nigra | 2 |
| P. alba x tacamahaca Mill | 2 |
| P. (grandidentata x canescens) x alba | 2 |
| P. (grandidentata x canescens) x deltoides | 2 |
| P. (grandidentata x canescens) x tremula | 2 |
| P. (grandidentata x canescens) x tacamahaca | 2 |
| P. (grandidentata x canescens) x nigra | 2 |
| P. deltoides x deltoides | 4 |
| P. deltoides x nigra | 1 |
| P. deltoides x Maximowiczii | 2 |
| P. deltoides x tacamahaca | 5 |
| P. nigra x deltoides | 1 |
| P. nigra x Maximowiczii | 2 |
| P. nigra x tacamahaca | 2 |
| P. tacamahaca x deltoides | 4 |
| P. tacamahaca x Maximowiczii | 4 |
| P. tacamahaca x nigra | 2 |

Most of the crosses with P. deltoides as female parent produced good seed, while the results with the rest of the crosses are very variable, with many failures.

Progeny Trials of Interspecific Hybrids

The full-sibs produced by artifical pollination have been planted in the field, in replicated field trials. These trials provide information on genetics and combining ability, and are also important sources of new clonal material. To date, nine progeny trials of interspecific hybrids have been established in southern Ontario, and three in northern Ontario.

New Clonal Selections

In 1980/81, the first clonal selections were made from 4 and 5-year old progeny trials of interspecific hybrids. The outstanding ortets

selected were of P. deltoides x Maximowiczii and P. deltoides x nigra parentage (2 clones from each).

Poplar Disease and Insect Resistence Studies

Studies have been initiated in cooperation and under contract with Dr. M. Hubbes[2] and Dr. R. Morris[3]. Investigations have been conducted in clonal trials across Southern Ontario. The disease survey concentrated on resistance to rust (Melampsora spp.), Marssonina leaf spots, Dotchichiza canker, and Septoria canker, while the insect survey focused on Cryptorhynchus lapathi L. and Prodiplosis morrisi Gagne. The data collected is useful in breeding and clonal selection, and contributes to the understanding of resistance mechanisms in poplar.

Cytogenetic Analyses

In cooperation and under contract with Dr. G. Filion[4], chromosomes in mitotic and meiotic divisions were studied in Populus intersectional hybrids and in trees which were treated with polyploidy-inducing agents at an early stage (Zufa, 1968). In some of these latter trees, the status of polyploidy was reinstated. Several hybrids showed a significant level of meiotic abberations, which could lead to sterility.

## BREEDING OF OTHER FAST GROWING DECIDUOUS SPECIES

Programs in willows (Salix L. spp) and alders (Alnus Mill spp) were initiated. An expansion and intensification of these programs is expected.

In willows, the selection and collection of specimens of importance for biomass production and their taxonomic identification has started in cooperation and under contract with Dr. J. Eckenwalder. The sampling is according to Hills' site districts and includes plant material for vegetative propagation and documentation of the collection.

An exploratory study in cytotaxonomy of willows has been accomplished in cooperation and under contract with Dr. Y. Raj[5]. The 2n chromosome numbers were checked in root-tips and expanding leaves. Species and interspecific hybrid specimens were included in the study. The results will contribute to the knowledge of taxonomical and genetical relationships in Salix species and hybrids and will help to formulate an effective breeding program. The study is continuing as part of the regular program.

In alders, a worldwide collection of specimens (half-sib seed collection) was started in cooperation with the International Energy Agency's Forestry Energy Program. To date, the following collections have been obtained:

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[2,3] Professor of Forest Pathology and Entomologist, Faculty of Forestry, University of Toronto (respectively)

[4] Associate Professor of Botany, Erindale College, University of Toronto

[5] Geneticists, Ontario Forest Research Centre, Maple, Ontario

Alnus cordata Desf. (18 collections); Alnus cremastogyne Burk (1); Alnus glutinosa (L.) Gaertn. (13); Alnus hirsuta (Spach) Rupr. (1); Alnus incana (L.) Moenck spp. tenuifolia Nutt (5); Alnus japonica (Thumb) Steud (1); Alnus jorullensis H.B.K. (1); Alnus nepalensis D. Don (1); Alnus rubra Bong. (45); Alnus sinuata (Reg) Rydb. (4); Alnus trabeculos Hand. (1); Alnus viridis DC ssp. fruticosa Rupr. (10).

The hybridization of alders by artifical pollination on bottle-grafted female-cones bearing branches was successfully attempted in A. glutinosa x rubra combination. The vegetative propagation of A. glutinosa and A. rugosa (Du Roi) Spreng by rooting lignified and green-wood cuttings in tented rooting beds was successful.

## WHITE PINE BREEDING

White pine breeding continued as outlined in 1977-78 progress report (Zsuffa, 1980). New series of interspecific hybrids were produced by artificial pollination. A study of blister rust resistance factors was initiated.

### Progeny Trials

To date, 85 half-sibs of plus trees have been included into six progeny trials. Of these, two are already outplanted, three are in nursery beds and one is in the greenhouse. The goal is to single out the best combiners and to identify superior progenies. Early results indicate very significant differences in progeny performance.

### Pollination

In 1980, artifical pollination was performed in 290 parent-tree combinations, including crosses of P. griffithii McClelland x strobus L., P. griffithii x (peuce Griseb x strobus), P. griffithii x cembra L. v. sibirica Loud, P. peuce x pumila Reg., P. strobus x cembra v. sibirica, P. strobus x peuce, P. strobus x pumila, P. (monticola Lamb x peuce) x strobus.

### Rangewide Sampling of P. griffithii

Rangewide collection by IUFRO of Himalayan white pine was obtained, and the seedlings outplanted in three areas in Southern Ontario. Early results suggest that only trees from very restricted sources from mountain altitudes can grow in Ontario.

### The Factors of Blister Rust Resistance

A study of protein patterns in needles of blister rust resistant and susceptible clones was initiated in cooperation and under contract with Dr. M. Hubbes. Needle samples were taken during the growing season from trees inoculated and free of disease. Early results indicate quantitative and qualitative differences in needle proteins of resistant and susceptible clones.

## FOREST GENETICS AND TREE BREEDING AT THE FACULTY OF FORESTRY, UNIVERSITY OF TORONTO

Since 1980, forest genetics and tree breeding has been offered as an elective one-term course for undergraduate students, and as a two-term course on the graduate level. The course is led by the author of this report, and assisted by tree breeders and geneticists of the Ontario Ministry of Natural Resources.

The fall, 1980 undergraduate program was attended by 35-4th year students. The graduate course was taken by three students. One Ph.D. candidate (Ms. K. Falusi) was accepted and started work on "Genetic variation in balsam poplar (P. balsamifera L.)", while the acceptance of another Ph.D. candidate is pending.

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# TREE GENETICS AND BREEDING, P.N.F.I.: JACK PINE GENETICS: 1979-1981

C.W. Yeatman

*Petawawa National Forestry Institute*
*Canadian Forestry Service*
*Chalk River, Ontario*
*K0J 1J0*

Key Words: Pinus banksiana, provenance, progeny test, breeding strategy.

Changes in personnel and program development are reported for the Tree Genetics and Breeding Project at P.N.F.I. All vacant positions have been filled as of July 1981.

A total of 60 foresters and technicians from Newfoundland to Manitoba attended three one-week courses to train Instructors in Tree Climbing for seed collection and breeding.

Research studies in jack pine have continued. Studies in red pine and Scots pine are on a maintenance basis. Jack pine range-wide provenance test data from New Brunswick, Quebec and Ontario were analyzed. Seed of selected Quebec provenances was sent to Dr. Darroll Skilling, U.S. Forest Service, for testing for resistance to the European strain of scleroderris canker. Work in cooperation with Ontario Ministry of Natural Resources included initiation of a jack pine seed orchard in Algonquin Park, establishment of northern tests of provenance hybrids and detailed discussions of applied breeding of jack pine in Ontario.

Research activities with spruce, larch and hardwoods are described elsewhere in these proceedings by G. Murray and T. Boyle.

## PERSONNEL

Changes in personnel, organization and responsibility following the formation of the Petawawa National Forestry Institute in April 1979 were outlined in the previous Proceedings (Carlisle 1980).

Dr. Gordon Murray joined the Project in August 1980 as leader of genetic research studies in deciduous hardwoods and larches. He subsequently assumed senior responsibility for studies in white and Norway spruces.

In January 1981, Mr. Timothy Boyle, formerly U.K. Forestry Commission, accepted a position of forestry officer and assistant geneticist, working primarily with Dr. Murray. Tim is to undertake graduate studies at the University of New Brunswick, commencing fall, 1981.

Dr. E.K. Morgenstern, formerly Project Leader, left PNFI in January, 1981, to take the position of Professor of Forest Genetics at University of New Brunswick, Fredericton. The author was appointed Project Leader and assumed senior responsibility for black and red spruce studies. The vacated position was designated forestry officer and assistant geneticist and staffed in May 1981 by Mr. W.M. Cheliak, Dept. of Forest Science, University of Alberta. Bill will remain at the University until spring 1982 to complete his Ph.D. studies on population structure and mating systems in jack pine.

Dr. Nikhil Bhattacharya, N.R.C. Post-doctoral Fellow, undertook studies of isoenzyme patterns of spruce and pine from September 1978 to December 1980 in collaboration with Dr. Murray during the period of the latter's sabbatical leave.

Mr. Jack Pitel, Biologist, and Mr. Garry Scheer, Technician, transferred from the seed to the Genetics Project in April 1981. Jack is responsible for the isoenzyme laboratory, analyzing seed and vegetative materials supplied by the research geneticists and also continuing to assist the Seed Project with biochemical analyses.

Mr. Paul Viidick retired as Superintendent of Planting Operations in December, 1980, to be succeeded by Mr. Tom Nieman who was formerly technician responsible to the author for work in the Jack pine study. The latter position was occupied in July 1981 by Mr. Peter Copis, who transferred to PNFI from the Great Lakes Forest Research Centre, Sault Ste. Marie.

To complete our present complement, Mr. Bazil Corbett has been appointed to a new and much needed position of Greenhouse Foreman. Bazil is a skilled grafter and is very knowledgable of all practical aspects of tree propagation following some seventeen years working with us on a seasonal basis.

## TRAINING

In addition to regular duties, the technical staff of the Genetics Project, together with Mr. Ernie Gilchrist of the Seed Project, assisted the author and Mr. Dave Winston in conducting three one-week courses in Tree Climbing, Genetics and Seed, two in 1979 and one in 1981. Some 60 Canadian foresters and technicians earned Tree Climbing Instructor's Certificates following practical and written examinations on safe tree climbing for seed collection and tree breeding.

Lectures, technical demonstrations and field exercises were given in 1980 and 1981 to students of Forest Technology, Algonquin College, Pembroke, in conjunction with their silviculture course. Brief genetics tours were also given to students from Toronto University School of Forestry and to third year forest technologists from Sir Sandford Fleming College, Lindsay, Ontario.

# JACK PINE GENETICS AND BREEDING

## Provenance

Analyses of 15-year growth data were completed for range-wide provenance tests planted at 12 locations in New Brunswick, Quebec and Ontario. The results corroborated those of the 10-year measurements and will be published. Climatic adaptation remains the dominant feature of provenance differentiations and genotype environment interaction at the population level. Local provenances are among the best in survival, growth, winter hardiness and disease tolerance at all sites with the exception of that at Caramat, north of Lake Superior and east of Lake Nipigon. Here trees from populations to the east and west within the boreal region are superior in growth, and trees of certain Quebec provenances had the lowest rates of infection by scleroderris canker (Gremmeniella abietina [Lagerb] Morelet).

Using seed supplied by the author, Dr. Darroll Skilling, U.S. Forest Service, found certain Quebec sources of jack pine to be tolerant to infection by the European strain of scleroderris canker in tests conducted in Upper New York State. The same seedlots also had a low infection rate of the North American strain when tested in Wisconsin (Skilling 1981; D.D. Skilling, pers. comm.).

Provenance hybrids were planted in 1980 at Petawawa and at two locations in northern Ontario, Kirkland Lake and Fraserdale. Inspection in the late spring, 1981, revealed clear patterns of winter damage at the northern test sites. Detailed analyses will follow.

## Selection and Progeny Testing

The first plantings were made in 1980 in the establishment of a demonstation jack pine seed orchard at Spoor Lake in eastern Algonquin Park. This applied research is being conducted in close collaboration with Mr. John Wilson, forester, Algonquin Park District, Ontario Ministry of Natural Resources. The project is also assisted by staff and students of the Forestry Department of Algonquin College, Pembroke.

The objectives are to: provide basic quantitative information of genetic parameters of jack pine; build a foundation population for research in advanced generation breeding; develop operational methodology and record costs for seed orchard management and the establishment of a predigreed breeding population; measure real gain achieved in productivity and quality of jack pine; and to produce genetically improved and regionally adapted seed for use in Algonquin and Pembroke Districts.

Pedigreed and mass-selection components of the seedling seed orchard were planted as well as a demonstration clonal orchard of grafted stock; progeny tests of over 300 open pollinated families are underway; and grafted clones of the parental plus trees are being established in a breeding arboretum.

Breeding

A diallel pollination scheme, including selfs and resiprocals, was completed among seven trees of local origin. It has taken several years to accumulate a minimum of 400 seeds for each combination. One of the randomly chosen trees proved to be a particularly recalcitrant seed parent.

Seed collection was also completed and the seed sown for a test of combining ability among plus trees within and between superior but geographically separate provenances growing at Petawawa. Bulked seed from mass-selected trees growing in young regeneration of fire origin formed the basis for a short term (10 years or less) nursery test planted at two spacings in 1981. The mass-selected material is being compared with three control lots of local origin.

Extension

Consultations were held with the Canadian International Paper Company concerning a jack pine breeding program for company forests north of LaTuque, Quebec. Detailed discussions were held with geneticists, breeders and field staff concerning applied breeding and seed production of jack pine required for central and northern Ontario.

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# RED AND BLACK SPRUCE GENETICS, PETAWAWA 1979-1980

E.K. Morgenstern

*Petawawa National Forestry Institute*[1/]
*Canadian Forestry Service*
*Chalk River, Ontario*
*K0J 1J0*

Key words: provenance, progeny, seed orchards, federal-provincial-industry cooperation.

The program with red spruce (Picea rubens Sarg.) and black spruce (Picea mariana [Mill.] B.S.P.) aims to develop a scientific basis for their genetic improvement. During the last two years some progress was made in measurement of experiments, the analysis of results and their publication.

This will be my last report from Petawawa. On 1 January 1981 I joined the Faculty of Forestry at the University of New Brunswick.

## PROVENANCE EXPERIMENTS

### Red spruce

Results from the nine experiments established between 1958 and 1960 in eastern Canada have been published jointly with Drs. Corriveau and Fowler (Morgenstern et al., 1981). The two most important findings at ages 15 and 22 years from seed were: (1) provenances from the southern Appalachian Mountains are not suitable for reforestation in Canada, and (2) the effects of introgressive hybridization with black spruce were still evident in this particular sample of provenances and influenced the results more than latitude, elevation or precipitation at the place of seed origin.

### Black spruce

The five Ontario experiments in the range-wide study were measured in 1979, i.e. at the age of 10 years from seed. The effects of grass competition and frost damage had not been overcome in some experiments so that a comprehensive evaluation was considered premature.

The earlier study, initiated in 1963 primarily with Ontario provenances, was remeasured in 1978. Strong interactions were observed, with very different responses at Chalk River and Kirkland Lake. The results will be published.

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1/ Present address: Dept. Forest Resources, Univ. New Brunswick, Bag 44555, Fredericton, N.B. E3B 6C2

## PROGENY TESTS

### Ontario Region 3E

The seven open-pollinated progeny tests in Kirkland Lake, Cochrane, Kapuskasing, Hearst, Chapleau, and Wawa (formerly White River) Districts completed their sixth year in the field and were measured for the first time in the fall of 1980.

### Ontario Regions 3W and 4S

These two test series, planted in 1976 and 1977, respectively, were visited and some maintenance performed by the cooperating forest districts. Their condition is generally satisfactory but minor maintenance is still required. In several of them more spring frost damage was observed than one would expect in this species, and some mortality due to Armillaria mellea [Vahl ex Fr.] Kummer was also identified.

### Controlled crosses

In 1979, two additional Petawawa experiments were measured: a) a field experiment with provenance hybrids (Exp. 358-B), b) the diallel cross of 1970, which consists of four test plantations. The data were summarized and stored in the computer.

## SEED PRODUCTION

Messrs. J.A. McPherson, B.S.P. Wang and I analysed the seed production of the grafted clonal black and white spruce (Picea glauca [Moench] Voss) seed orchards of Kimberly-Clark of Canada Ltd. at Longlac, Ontario. The orchards had been gradually established since 1960 and have been monitored since 1970. Although there was wide fluctuation from year to year in flowering, all ramets flowered in the best seed years. In 1980 a bumper crop was harvested in the white spruce orchard. The two orchards are probably the oldest of their kind in Canada and statistics from them will be of great interest. A paper has been submitted for publication (McPherson et al., 1981).

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# GENETICS OF LARCHES AND DECIDUOUS HARDWOODS, PETAWAWA, 1978-1981

G. Murray

*Petawawa National Forestry Institute*
*Canadian Forestry Service*
*Chalk River, Ontario*
*K0J 1J0*

Key Words: Larix decidua, Larix leptolepis, Larix laricina seed collection, seed production area, progeny test.

Responsibility for studies of native and exotic larches (Larix Mill.), black walnut (Juglans nigra L.), white and green ash (Fraxinus americana L. and Fraxinus pennsylvanica Marsh.), and Norway maple (Acer platanoides L.) was assumed by Dr. G. Murray in June 1980 when he filled the position left vacant for about 18 months following the resignation of Mr. R.F. Calvert. During this interim period, work already started, much of it involving cooperation with other agencies, was continued by Mr. John Veen, research technician, with the guidance of Dr. Morgenstern and Dr. Yeatman. Since June 1980, a review of the work in progress has led to some changes in priorities, the result of which will be to direct more attention to genetic studies on larch.

## LARCHES

### Exotic larches

Plantations established at Petawawa in 1953 and 1961 with different seedlots of European larch (Larix decidua Mill.), Japanese larch (Larix leptolepis [Sieb. and Zucc.] Gord.), and hybrid larch (Larix eurolepis Henry) were thinned during the winter of 1979/80. This thinning, the purpose of which was to favour selected trees, yielded an estimated 145 cubic metres of merchantable larch logs from a total area of 1.8 hectares. The bulk of these thinnings was used in tests of pulping and paper making properties conducted by Domtar technical services staff at their plant in East Angus, Quebec. Results of this work will be published.

Seed of 79 seedlots of Japanese larch, representing collections from trees in native stands in Japan and in plantations in Japan, Europe, and Canada, were sown in containers at P.N.F.I. in June 1978 and the seedlings were transplanted in the Ontario Ministry of Natural Resources (O.M.N.R.) nursery at Kemptville in August of the same year. In 1979 these trees were planted by O.M.N.R. at two locations near Cornwall and Ottawa, and by the Canadian International Paper Company (C.I.P.) near Trois Rivières, Quebec, according to a design for a seed production area suggested by

Dr. C.W. Yeatman. The objective of this design was the creation of seed production areas in which five percent of the trees planted would ultimately be retained for seed production following selection for hardiness, freedom from pests, growth rate, and stem and crown form.

About 45 of these Japanese larch seedlots were also included in several plantations established in eastern Ontario in 1980 as part of the ENFOR (Energy from the Forest) program carried out by O.M.N.R. under contract.

Scions from superior phenotypes of European larch selected in P.N.F.I. plantations were provided for inclusion in Japanese x European hybrid larch seed orchards being established by O.M.N.R. near Napanee, and by C.I.P. at Harrington, Quebec. Scions from these and other selected trees have also been grafted at P.N.F.I. where they will be used in future breeding work.

Native larch

Since 1977, cooperators in the range-wide provenance study of tamarack (Larix laricina [Du Roi] K. Koch) have received requests for collections of seeds from stands in given areas. Responses to these requests have indicated a high level of interest in this study, but poor seed years, seed losses to insects, and the short period between cone maturity and seed fall have made collection of the required seed very difficult. For example, cone collections in the maritime provinces and in the state of Maine have yielded no significant amounts of seed. Cones have been received from 35 different stands in Ontario, but in only eight cases have these yielded adequate amounts of seed from ten trees in the stand. No collections have been made in Manitoba, while seed were obtained from four stands across central Saskatchewan, and from one stand in Wisconsin. Finally, offers of seed from earlier collections have been received from Quebec and Alberta.

These difficulties in obtaining adequate supplies of tamarack seed were not unexpected, and it was stated in the original proposal that it could take until 1982 to assemble the required seed. Efforts to satisfactorily complete collection of the seed will continue in 1981.

## DECIDUOUS HARDWOODS

White ash progeny tests, including seed from Ontario, Quebec, and New Brunswick, were planted in 1980 and 1981 near Orono, Ontario, and Portage-du-Fort, Quebec, with the cooperation of O.M.N.R. and Consolidated Bathurst Ltd. at the respective locations. A white ash provenance test, planted at Petawawa in 1977 as one of a series of tests organized by the U.S. Forest Service, was evaluated for survival, growth, and frost injury and the data sent to Dr. Knud Clausen at the North Central Forest Experiment Station, Carbondale, Illinois. Green ash from Ontario, Quebec and the Maritimes were planted in a number of provenance tests, most of which were part of the ENFOR program in eastern Ontario.

Five black walnut progeny tests were planted in 1978 and 1979 as part of a cooperative P.N.F.I.-O.M.N.R. study. Survival in two of these

plantations was very poor and a third plantation was lost when the farm on which it had been planted was sold. Recently, full responsibility for the tests was transferred to O.M.N.R., marking the increasing level of interest and activity in gene conservation and genetic improvement in black walnut within O.M.N.R.

Norway maple seed obtained from three widely separated locations in the Soviet Union in 1977 were grown in the nursery at P.N.F.I. and the seedlings were planted at two locations at P.N.F.I. in 1981. In future years these trees will be evaluated on the basis of their hardiness, growth rate, and stem and crown form.

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# WHITE SPRUCE GENETICS, PETAWAWA 1978-1981

G. Murray and T.G. Boyle

*Petawawa National Forestry Institute*
*Canadian Forestry Service*
*Chalk River, Ontario*
*K0J 1J0*

Key Words: provenance, progeny test, isoenzymes.

A number of personnel changes in the past two years have tended to limit research activity on white spruce genetics to continuation of studies already in progress when Dr. Ying resigned in July 1979. Essential work on provenance and progeny tests was carried out by Mr. Hoelke, research technician, under the supervision of Dr. Morgenstern, while isoenzyme studies were continued by Dr. Bhattacharya and Dr. Murray. When Dr. Morgenstern left to join the faculty at the University of New Brunswick in January 1981, responsibility for the white spruce studies passed to Dr. Murray assisted by Mr. Boyle, who joined the tree genetics and breeding project as a forestry officer in January.

## PROVENANCE STUDIES

Three more field tests forming part of the range-wide provenance study described by Ying (1980) were planted in Ontario in cooperation with the O.M.N.R.(Ontario Ministry of Natural Resources). Staff from P.N.F.I. supervised the planting, near Sudbury, of one range-wide test that included 86 provenances arranged in five replicates with square nine-tree plots. Two regional tests were planted near Chapleau and Minden under the supervision of Mr. Skeates of O.M.N.R. Planting stock for two additional range-wide tests will be ready for field planting in 1982 and 1984.

One regional test, planted near Red Lake, Ontario, in 1978 was burnt in the spring of 1980. To replace this test, seed were sown in the greenhouse at P.N.F.I. in November 1980 with the objective of producing container stock suitable for field planting in the spring of 1982.

During 1978 and 1979, 15- and 20-year survival counts, and measurements of height and, in some cases, diameter, were taken in the earlier series of tests described by Teich, Skeates, and Morgenstern (1975). Parts of several of these plantations had been destroyed or damaged by agents such as fire, frost, and insects, but preliminary analysis of the height data showed that there had been few significant changes in the ranking of provenances in the surviving plots. Seed sources from Southern Ontario, the Ottawa Valley, and the Lower St. Lawrence had maintained their

superiority in tests at Owen Sound, Dorset, Lake Dore, Chalk River, and Thunder Bay. In two tests at Kapuskasing, sources from Northeastern Ontario and Quebec were still tallest but, in one of the tests, a provenance from near Thunder Bay had risen from 11th to 3rd in rank and from 102% to 125% of the overall experimental mean height. These data are being prepared for publication.

## PROGENY TESTS

Two progeny tests were planted in 1980, one at P.N.F.I. and the other near North Bay, both located in Ontario site region 5E. The open-pollinated seed used were part of the collection made for the range-wide provenance study and came from 239 trees in 30 stands within, or immediately adjacent to site region 5E.

## ISOENZYME STUDIES

Distribution of isoenzymes in a natural stand of white spruce was studied using seed from 48 trees. Dr. N.C. Bhattacharya, a Visiting Fellow sponsored by the Natural Sciences and Engineering Research Council of Canada, modified standard techniques of starch gel electrophoresis for the analysis of isoenzymes in crude extracts of white spruce megagametophyte tissue. Only two enzyme systems, GDH (glutamate dehydrogenase) and MDH (malate dehydrogenase), produced band patterns that were sufficiently clear and consistent to permit genetic interpretation of the results. Genotypic frequencies calculated on the basis of allelic frequencies observed in this population did not differ significantly from those expected in a panmictic population. A short paper based on these results will be presented by Dr. Murray at the second conference of the North Central Tree Improvement Association in Lincoln, Nebraska in 1981.

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# NATIONAL TREE SEED CENTRE, 1979-80

B.S.P. Wang, D.A. Winston, B.D. Haddon and J.A. Pitel

*Petawawa National Forestry Institute*
*Canadian Forestry Service*
*Chalk River, Ontario*
*K0J 1J0*

Key Words: Germplasm Bank, processing, testing, artificial ripening, dormancy, storage, seed crop management.

In the last two years the National Tree Seed Centre has continuously expanded its program from five to seven studies with increased funding. The newly initiated research studies were on artificial ripening of tree seed, and predicting and evaluating cone crops and losses due to insects.

From April 1, 1981 Jack Pitel and his technical assistant, Garry Scheer, will be transferred from the current study on biochemical techniques and indices for seed quality control to biochemical systematics, such as isoenzyme studies of forest trees, within the Tree Genetics and Tree Breeding Project. However, Jack will still work in close cooperation with the staff of the Seed Centre. The Centre successfully organized and hosted the 1980 IUFRO International Symposium on Forest Tree Seed Storage with pre- and post-symposium field trips to northern and southern Ontario hosted by the Ontario Ministry of Natural Resources (OMNR).

In this paper we report the progress made in our studies on forest Germplasm Bank and associated services; testing, treatment and storage of tree seed; seed crop production and stimulation; and the two new studies. The progress on the study of control of insect and fungal pests in seed production and distribution and storage is reported separately by Dr. Willard Fogal.

## SERVICE

### Seed Procurement, Distribution and Processing

In addition to serving as a repository for forest seed and other reproductive material, the Germplasm Bank serves as a clearing house for procurement and distribution. Numerous seedlots have been received from several sources in the U.S.S.R. and the People's Republic of China and distributed to requesting agencies across Canada. A sample of sugar maple (Acer saccharum Marsh.) seeds was recently received from the U.S. Forest Service which should be of particular interest to maple syrup researchers as it was collected from clones selected for superior sap sugar production.

The Germplasm Bank will serve as the North American centre for the International Energy Agency's project, "The Collection and Distribution of Seeds of Alnus Species which are of Importance for Biomass Production in Energy Plantations".

The Centre cooperated with the Ontario Ministry of Natural Resources in an evaluation of black spruce (Picea mariana [Mill.] B.S.P.) seed yields and quality obtained from mechanical cone collection trials.

For the past 10 years Kimberly-Clark of Canada Limited has sent for custom processing cones from its black spruce and white spruce (P. glauca [Moench] Voss) seed orchards at Longlac, Ontario.
Processing and storage services were extended to the Eastern Region of the Ontario Ministry of Natural Resources for its larch program.

A chapter on white spruce (Skeates et al. 1981) and one on red spruce (P. rubens Sarg.) and Norway spruce (P. abies [L.] Karst.) have been submitted for the Ontario seed collection manual currently in preparation. A report on seed procurement and processing across Canada is in preparation as part of the Canadian Forestry Service Forest Resource Data Program.

Seed Testing and Seed Crop Evaluation

Over 2,000 separate tests of 400 seed samples were made for purity analysis, germination, moisture content determination, 1,000-seed-weight determination and x-ray analysis, although the number of commercial tests has greatly declined since the Pacific Forest Research Centre has become an accredited official tree seed testing station with the International Seed Testing Association. Miss Francine Sheridan was newly appointed as an official seed analyst for the Canada Seeds Act.

Wang worked closely with Canadian Forestry Service (CFS) Headquarters and other CFS establishments to assist Agriculture Canada in drafting an amendment to the current Canada Seeds Act to bring about the transfer of all forest tree seed control from Agriculture to CFS and to develop the first draft of new forest tree seed regulations for review.

Because of the variations among replicated samples experienced in both service and research testing of tree seed, a close examination of causes indicated that moisture in the germination medium and the type of germination trays used appeared to be the two principal sources of the variation. In order to overcome this problem, a standard germination box was developed and a contract signed with Spencer-Lemaire Industries of Edmonton for manufacturing proto-types for testing. It is hoped that commercial production of the boxes will be followed after the testing.

The seed laboratory successfully participated in three International referee testing projects: (1) to evaluate prechilling treatment for Abies concolor (Gord & Glend.) Lindl. and A. procera Rehd. seeds, (2) to determine empty seed of P. Abies, and Pinus sylvestris L. after germination test by x-rays and cutting method and (3) to compare rapid viability tests with standard germination tests for A. alba Mill., A. pseudoplatanus L. and Fagus sylvatica L. seeds.

In an evaluation of white spruce seed quality for the Alberta Forest Service, it was found that the low germination was possibly due to the change of seed moisture content and mishandling of cones after collection.

Seed crop assessment services were provided to the Ontario Ministry of Natural Resources and the Nova Scotia Department of Lands and Forests. It was found that the x-ray technique is very useful for evaluating yellow birch (Betula alleghaniensis Britton) seed crops and determining collectability. Seeds extracted from cones collected from black spruce trees after one month from logging (early August) showed 74-80% germination without chilling but 45% germination with chilling. The results will be further confirmed by duplicated trials in 1981.

## RESEARCH

### Seed Extraction and Cleaning

A small study of moisture content of jack pine (Pinus banksiana Lamb.) seeds during extraction and cleaning was carried out in response to a question which had arisen concerning the tolerance of seeds to low moisture content. Seed moisture content immediately after extraction was very low; just over 2% (fresh weight basis). A study of the effect of initial cone moisture content on cone opening and seed yields of tamarack (Larix laricina [Du Roi] K. Koch) was initiated.

Seeds of alder (Alnus) are difficult to clean. An effective method to up-grade alder seed quality was found to be by liquid separation. A report is being prepared.

### Seed Dormancy

Further studies on dormancy problems of whitebark pine (P. albicaulis Engelm.), lodgepole pine (P. contorta Dougl.), red maple (A. rubrum L.), ironwood (Ostrya virginiana [Mill.] K. Koch) and basswood (Tilia americana L.) were completed. Results of these studies have been either published or are in the process of being published. Treatments involved in these studies included acid scarification, chipping, prechilling, exogenous application of hormones and a combination of the treatments.

Studies were carried out to determine some of the fundamental causes of dormancy such as the examination of growth inhibitors, amino acids, isoenzymes and chromosomal proteins during prechilling. As part of an international cooperative research project, a review of literature dealing with deeply dormant tree and shrub seeds is in the final stages of completion.

### Seed Germination

An experiment to improve the current germinability testing method of white ash (Fraxinus americana L.) and red ash (F. pennsylvanica Marsh.) seeds was completed and a report is being prepared. Cooperative research with the Alberta Forest Service on lodgepole pine seed germination and effects of seed weight on germination and early seedling development was

completed and a technical report was published by the Alberta Forest Service. The report recommends the prechilling requirements for maximum lodgepole pine seed germination, and the importance of seed weight on seed germination vigor and early seedling development.

Preliminary research on Alnus germination requirements indicated that the primary cause of low germinability was due to incomplete seed cleaning, sensitivity of the seed to moisture of the medium and photoperiod in germination. Further research on the ecology of Alnus seed germination is in progress.

Experiments have been initiated to test a hypothesis of the endogenous control of germination rhythm in white spruce and jack and lodgepole pine seeds. Data from the first year experiment are being analyzed for reporting.

In a cooperative research on seed production with Dr. Morgenstern (UNB) and Mr. McPherson (Kimberly-Clark), evaluation of seed quality of white and black spruce from Kimberly-Clark seed orchards has been made since 1970, and a paper has been jointly prepared for publication.

New studies on the ecology of germination of native tree species will be initiated in 1981.

Seed Storage

Seeds from a long-term storage study to test the effectiveness of the two storage conditions at Petawawa National Forestry Institute were evaluated after 11-13 years and a paper entitled "Long-term storage of Abies, Betula, Larix, Picea, Pinus and Populus seeds" was presented at the 1980 IUFRO International Symposium on Forest Tree Seed Storage held at the Institute. Another paper entitled "Accelerated aging studies of seeds of jack pine (Pinus banksiana Lamb.) and red oak (Quercus rubra L.)" was also presented at the same symposium. Findings from the former experiment showed that sub-freezing temperature ($-18^{o}C$) is positively superior to above freezing temperature ($2^{o}C$) for long-term storage of A. balsamea (L.) Mill., P. glauca, P. strobus L., Populus deltoides var. occidentalis Rhdb., P. grandidentata Michx. and B. alleghaniensis seeds. Results from the latter study suggest that the loss of germination and vigor of seeds was associated with membrane damage, degradation of reserve proteins, increases in the levels of soluble amino acids, and with minor structural changes of the chromosomal proteins, ribosomal proteins and isoenzymes. A preliminary report describing the amino acid composition of various coniferous and hardwood seeds has been prepared.

New seed storage experiments are being established to examine the effects of prolonged storage on chromosomal changes and the beneficial effects of freeze-drying on seed storage life. A new study will be established to test the suitability of liquid nitrogen as a long-term, ex situ storage condition for forest gene-pool conservation measures.

Seed Crop Management: Forecasting, production and early collection

As a result of a very intensive review of the literature and a survey of most client agencies, a series of research priorities were established for future action in seed crop management. Winston will devote a majority of his time to study factors affecting the production and stimulation of seed crops. Several experiments have been established during 1979-81 examining the effects of spacing and fertilizers on cone production. Applications of the fertilizer, ammonium nitrate (34%N), at the time of vegetative bud flushing to stimulate cone production are being tested at Angus, Ontario in a white spruce seed orchard and at Mackey, Ontario in a red pine seed production area. Six major experiments have been established, in cooperation with W. Fogal (PNFI) and OMNR in both white spruce and black spruce plantations. These trials are designed to test the effects of ammonium nitrate fertilizer, alone and in conjunction with the chemical insecticide carbofuran for control of cone and seed insects, as a means of increasing cone production. Preliminary results are encouraging and further results are being analysed. The effects of frost on the regulation of flowering, while often mentioned, have not been well documented in the literature. Current observations indicate severe frost damage to potential white spruce crops occurred throughout north-eastern Ontario and to red pine (P. resinosa Ait.) in central Ontario in 1980. Similarly, tamarack crops in central Ontario have been damaged in 1981. In cooperation with the OMNR, a detailed assessment of frost damage to flowers in a red pine plantation is underway at Mackey, Ontario.

Problems related to cone collection are being addressed by Haddon and Winston. Experiments have been ongoing since 1978 to determine optimum cone collection periods for different species and to determine if the cone collection periods can be extended through the use of artificial ripening techniques. Results to date indicate that both white spruce and red pine cones can be collected early and ripened artificially to produce healthy, germinable seed (Winston and Haddon 1981). White spruce collected as early as August 1 could be ripened when stored for 12 weeks in a room at 5°C with 75%-95% relative humidity. Conversely, red pine was successfully ripened in the PNFI cone air-drying shack when stored for at least 4 weeks after collection as early as August 23. Cold-air (5°C) storage of white spruce cones was found to eliminate the need for prechilling of white spruce seed to permit germination. This suggests that prechilling requirements of seed may be affected by cone handling and storage conditions. The retention of germinability of artificially ripened seed was tested following two years of seed storage (Haddon and Winston 1981). In most seedlots, both germinability and fulfillment of prechilling requirements as a result of cone storage at 5°C were found to be retained. Further studies are continuing with other species (tamarack, white pine) and new directions are being initiated to more fully document embryo development in seed of native Canadian tree species and the role/relationships of embryo growth to seed maturation.

The forecasting and recognition of potential seed crops is being examined in detail by Winston and Fogal. To date, a series of experiments have been initiated which include sampling buds of white spruce and black spruce in winter conditions and attempts are being made to relate these to potential cone crop. This utilizes the methodology reported by Eis (1967,

1973) and Eis and Inkster (1973) with adaptation to eastern Canada. However, our studies are examining losses to cone and seed insects and should provide more reliability on final crop estimates. In cooperation with the OMNR, a cone collection manual for Ontario is being prepared. A chapter on forecasting methods has been written and techniques for recognizing buds and flowers of spruces have been documented.

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# INSECT AND DISEASE RESEARCH IN TREE IMPROVEMENT AND SEED PRODUCTION--PETAWAWA, 1979-80

W.H. Fogal

*Petawawa National Forestry Institute*
*Canadian Forestry Service*
*Chalk River, Ontario*
*K0J 1J0*

Keywords: spruce, seed and cone insects, seed losses, forecasting, sex pheromones, chemical control, biological control, susceptibility, tolerance, phytochemicals.

## INTRODUCTION

Research on insects and diseases at Petawawa National Forestry Institute (PNFI) focuses on problems that are a threat to forest regeneration in boreal and eastern Canada. One study is concerned with the use of genetics and breeding in forest pest management and has as its objectives identification of pest-tolerant trees and development of guidelines to prevent planting of susceptible types in forest regeneration. A second deals with management and control of insect and disease problems in production, collection, storage, and germination of seed. Background rationale for these two studies was outlined in a previous report (Fogal 1980a).

Serious shortages of black spruce, (Picea mariana [Mill] B.S.P.) and white spruce, (Picea glauca [Moench] Voss), seed have prompted us to concentrate our research effort over the past two years on control of losses to insects in these two species. This report outlines our activities and progress for the period 1979-80. It also includes a brief outline of insect pests and fungal diseases which have been investigated as part of tree-improvement studies at Petawawa.

## SEED AND CONE INSECTS: WHITE AND BLACK SPRUCE

Spruce budworm, Choristoneura fumiferana Clem., coneworm, Dioryctria reniculleloides Mutuura and Munroe, seed moth, Laspeyresia youngana (Kearfott), cone maggot, Lasiomma anthracina (Czerny), and other insects are responsible for shortfalls of white and black spruce seed and are a threat to tree improvement in these species in boreal and eastern Canada. We are seeking solutions by developing an integrated pest management approach that includes evaluation of seed losses, pest monitoring, crop forecasting, control with chemicals and biocides.

Evaluation of Losses, Insect Monitoring and Crop Forecasting

Cone crops, seed yields, and insect damage are being determined to evaluate losses to insects in a variety of tree habitats ranging from unmanaged seed collection areas to intensively managed clonal seed orchards in cooperation with the Ontario Ministry of Natural Resources, Dryden and Kapuskasing districts and Kimberly-Clark of Canada Limited, Longlac, Ontario. Results are beginning to provide valuable information about which insects cause most serious losses, when and where to collect cones in natural stands, and effects of various types and levels of crop management on seed yields and losses to insects (Fogal 1979).

The use of insect sex pheromones to monitor populations of seed moth is being investigated in cooperation with Dr. G.G. Grant, Forest Pest Management Institute, Sault Ste. Marie, Ontario. Field tests were begun in 1980 at PNFI to find an effective and reliable lure for the seed moth and to monitor its population levels and flight season. Twelve lure mixtures, using (E)-7 dodecenal as the principle ingredient, were tested. Choice of effective lures is confounded by differences in infestation levels and by trapping of closely related moths. However, a good picture of the flight season in relation to weather factors and phenology of flowering is emerging (Grant 1980).

A study on crop forecasting and prediction of losses to insects was initiated in 1980 in cooperation with Mr. D.A. Winston to determine possible relationships between crop sizes and insect losses and to develop means for predicting size of white and black spruce cone crops for at least one year in advance of collecting.

Chemical Control

Foliar treatments of a range of concentrations (0.5 to 1.5 percent active ingredient) of dimethoate, lannate, and orthene applied to cone-bearing portions of white spruce trees were carried out in 1978 and 1979 for protection from budworm, coneworm, seed moth, cone maggot, and other insects. The degree of protection appears to be related to tree size.

Stem applications of dimethoate and oxydemeton-methyl in 1980 provided some protection of seed crops from seed moth, coneworm, and cone maggot (Fogal 1980b). Experiments have been started with Mr. V.C. Plowman, Farm and Forest Research Limited, Oakville, Ontario and Dr. E.S. Kondo, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario to test systemic insecticide injections for control of seed and cone insects in white spruce. This method of insecticide application will reduce environmental hazards to a minimum.

In 1979 and 1980, experiments were begun with D.A. Winston to assess soil applications of carbofuran insecticide and ammonium nitrate as management tools in white and black spruce plantations at the Bonnor Tree Improvement Centre, Ontario Ministry of Natural Resources, Kapuskasing, Ontario. Results to date are very encouraging with respect to budworm control and cone crop stimulation (Fogal 1980b; Fogal et al in press).

Biological Control

Studies were initiated in 1979 and continued in 1980 in cooperation with Dr. M.I. Timonin, Carleton University to determine whether entomopathogenic fungi can be used for control of seed and cone insect pests in white spruce. Several insects that attack cones of white spruce are highly susceptible to infection by Beauveria bassiana (Bals.) Veuill. and Metarrhizium anisopliae (Metch.) Sor. (Timonin et al., 1980). Methods for delivering spores to target insects must be devised.

## INSECTS AND DISEASES IN TREE IMPROVEMENT STUDIES

Consideration of variations in susceptibility of native and exotic trees to native and introduced pests has been an integral part of the Petawawa tree improvement program since its inception in 1924. Mortality and damage caused by insects or disease have been carefully recorded for many years in provenance trials, plus-tree selections, and progeny testing. The following fungal diseases and insect pests have been studied: scleroderris canker, Gremmeniella abietina (Lagerb) Morelet; shoestring root rot, Armilleriella mellea (Vahl ex Fr.) Karst.; sweetfern blister rust, Cronartium comptoniae Arth.; pine gall rust, Endocronartium harknessii (J.P. Moore) V. Hiratsuka; larch sawfly, Pristiphora erichsonii Htg; introduced pine sawfly, Diprion similis Htg; white pine weevil, Pissodes strobi Peck. A review of literature on variation in susceptibility of native and introduced coniferous trees to some insects of eastern Canada has been accepted for publication (Fogal et al., in press).

Phytochemicals that influence insect host preference and protect plants from disease organisms are believed to play an important role along with other factors in acceptability of trees as hosts for insect and disease organisms. Identification of such chemicals in host or non-host plants can lead to their eventual manufacture and use for application in pest control and simple measurements in host tissue may help breeders select tolerant trees. Possible applications to the spruce budworm have been outlined elsewhere (Strunz and Fogal, in press; Fogal and Strunz, in press).

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# SOME ACTIVITIES RELATED TO FOREST GENETICS AT LAKEHEAD UNIVERSITY, 1979-1981

William H. Parker

*School of Forestry and Department of Biology*
*Lakehead University*
*Thunder Bay, Ontario*
*P7B 5E1*

Key Words: phenology, seed orchard, ecotypic variation, population differentiation, needle flavonoids, species-pairs.

Forest genetics remains as one focal point of teaching and research at the School of Forestry. During the past two years Dr. Gordon Murray and Dr. John Barker have each moved on to new positions, but they have been replaced by Dr. Rob Farmer (formerly of Tennessee Valley Authority) and Dr. Peggy Knowles (formerly at University of Colorado, Boulder). Dr. Farmer will be investigating the genecology of poplars and other species in the boreal forest, and Dr. Knowles has begun an investigation of isozyme variation within reforested stands of Pinus banksiana Lamb. My own activities have focused on morphological and flavonoid variation in natural stands of Abies and Picea.

## DEGREE OF SELFING IN A BLACK SPRUCE SEED ORCHARD

Mr. Conor O'Reilly recently completed his M.Sc. Degree investigating vegetative and sexual phenology of Picea mariana (Mill.) B.S.P. To estimate the amount of self-pollination in a clonal seed orchard of Picea mariana, periods of pollen release and female receptivity were determined for 4 ramets each of 14 clones located in the Matawin Seed Orchard, Thunder Bay District, Ontario. Stages of pollen release and female receptivity were determined by a qualitative index, and total numbers of male and female strobili were counted. Although the overall duration of pollen release and female receptivity was short, consisting of about 15 days, significant differences in timing were present between clones. However, peak pollen release and maximum female receptivity coincided for most clones, thus increasing the probability of self-pollination. Numbers of both male and female strobili were significantly different between clones, with a few of the clones producing the largest numbers of strobili; this effect was most pronounced for male strobili. As well, clones producing large numbers of male strobili did not necessarily produce large numbers of female strobili. The genetic composition of the seed crop was estimated from 1) the daily stages of pollen release and female receptivity and 2) the number of male and female strobili per clone. A small fraction of the 14 clones made the largest contribution to the genetic composition of the progeny. This result depended most heavily on numbers of male strobili produced by each clone, while the

timing of pollen release and female receptivity had little effect. The average percentage of self-pollination was estimated at 9 per cent, but individual clones varied from 1 to 25 per cent.

## UPLAND AND LOWLAND VARIATION IN BLACK SPRUCE

Dr. Knowles, several graduate students, and myself have been investigating variation in upland and lowland stands of black spruce. Picea mariana is widely distributed, genetically variable forest species that occuppies ecologically diverse sites in northwestern Ontario. In this area black spruce trees growing on bog sites are stunted and appear strikingly different from nearby forest trees. To determine whether site differences have led to ecotypic differentiation, 10 cone-bearing trees were sampled from each of the following three semi-adjacent stands near the Matawin River, Thunder Bay District, Ontario: 1) an upland forest on well-drained alluvial soil, 2) an abandoned pasture on heavy soil, and 3) a very wet sphagnum bog. Nine cone characters and 8 needle and twig characters were scored for each tree, and these data were analyzed by Principal Components Analysis (PCA) and Canonical Variates Analysis. PCA demonstrated that two major, independent trends of variation existed in the data, one attributable mainly to cone characters and the other attributable mainly to needle characters. Bog trees were slightly differentiated from tree from the drier sites based on cone data, but the differences were not significant. Also, bog trees were more variable than the others with respect to cone characters, but not needle or twig characters. The trees also were compared on the basis of foliar flavonoids. A fraction of the bog trees possessed a flavonoid glycosylation class not present in the other trees indicating greater chemical diversity in the bog trees that paralleled the greater variation in cone characters. Bog and forest trees were further compared using isoenzymes, no differences between sites were detected. Results of morphological and chemical analyses indicate that bog trees are more variable for certain functionally-related groups of traits including cone and flavonoid characters, but not for needle, twig, and isozyme characters. However, discrete ecotypes corresponding to upland and lowland sites could not be distinguished in the sampled trees.

## GENECOLOGY OF NORTH AMERICAN ABIES SPECIES

Together with Dr. Jack Maze at the University of British Columbia, and several students, I have been investigating relationships between certain species-pairs of Abies and the nature of variation within the balsam firs and noble firs. Abies balsamea and A. lasiocarpa are closely related North American balsam firs that are generally thought to hybridize and intergrade where their ranges overlap in west-central Alberta. To test this hypothesis, a series of collections was made from 10 populations along an east-west transect between western Saskatchewan and central British Columbia. Each tree was scored for various vegetative and cone characters. The resulting data were analyzed by Principal Components Analysis and Canonical Variates Analysis. Analyses based on vegetative data produced somewhat different results

from analyses based on cone data indicating that vegetative and sexual features of the trees respond to different selection pressures at the ecologically diverse sample sites. The combined results of analyses of vegetative and sexual data indicate that the 10 populations do not represent elements of two morphologically distinct taxa. Instead, the results apparently reflect population differentation within a single, regionally variable complex in response to local selection pressures following east-west gene flow. It is recommended that the separate species designations, A. balsamea and A. lasiocarpa, be retained since 1) present day elements of the complex are evidently derived from separate refugia isolated by the Rocky Mountains during past glacial periods, and 2) gradual morphological differences exist between populations on each side of the Rocky Mountain crest.

Student Projects in Progress

1. Implications of needle flavonoid variation on the relationship of Abies procera to A. magnifica.

2. Comparison of phenotypic plasticity in upland and lowland clones of Thuja occidentalis under adaptive and non-adaptive conditions.

3. Alternate methods of Picea mariana plus-tree selection emphasizing competitive performance.

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# A REGIONAL RARE WOODY-PLANT PROGRAM FOR SOUTHERN ONTARIO

John D. Ambrose

*University of Guelph Arboretum*
*Guelph, Ontario*
*N1G 2W1*

Key Words: forest gene resources, Deciduous Forest Region.

The Deciduous Forest Region occurs in extreme southern Ontario along a narrow band above the southern Great Lakes. In the biologically diverse forests of this region, many species of eastern North America reach their northern limits of distribution. While these Carolinian species are considered rare due to their restricted distribution in Ontario (Argus and White, 1977), many are also threatened due to loss of habitat associated with the high level of human activity here. Beyond the recognized need to conserve critical habitats, this program's objectives are to survey, collect seeds of, and gene bank the rare woody plants of Ontario. While this program is co-ordinated through the Arboretum, considerable support is received from a province-wide network of Arboretum Associates.

## THE ONTARIO RARE WOODY PLANT PROGRAM

The program is now assessing the current status of 52 species of rare woody plants. While most of these have typical Carolinian distributions (e.g., Liriodendron tulipifera L., Quercus muehlenbergii Engelm.), a few have limited western (e.g., Oplopanax horridus (Sm.) Miq.) or eastern (e.g., Pinus rigida Mill.) distributions. Most of the Ontario populations of these species represent the northern limits of their distributions. These may represent genetic variants not present farther south or elsewhere through the species range due to their disjunct distribution or isolation by the Great Lakes. Thus, they represent a regional resource worthy of recognition and conservation, both to maintain the genetic diversity of the species as well as provenances likely best suited for economic utilization in Canada.

The documentation of the current natural occurrence of these species has allowed a better assessment of their status in Ontario. Duplicate herbarium specimens are being sent to the National Museum of Natural Science where they will be useful in the Rare Plant Atlas Project. As species are identified as potentially threatened or endangered in Ontario, attention can be drawn to the need for more detailed studies.

The collection of seeds of these rare species offers an unusual focus to our international seed exchange program. By extending the effec-

tive reservoir of documented collections of Ontario populations to botanical institutions around the world, we might at some time in the future be able to draw on this expanded distribution for various types of evaluation data, or even propagation material.

Many of the seed collections are also being grown in our nursery facilities for inclusion in the Gene Bank Collection. Here we would like to ideally include as much genetic variation as is identified in Ontario populations, providing a suitable resource for a future selection and breeding program.

Habitat conservation is an essential concern of forestry gene resources. This program is meant to complement--not supplant--that equally important concern. Even under good forestry management practices, most of these species are threatened due to their current status as non-commercial species. When provinically significant habitats are identified through this program, such information will be communicated to the Ministry of Natural Resources for consideration in the Nature Reserve system.

## PROGRESS

During the past year, approximately 250 sightings or herbarium specimens of rare woody species were recorded. Of 142 seed collections of native plants for the Arboretum's Index Seminum, 50 were of rare woody species. These were distributed to 132 requesting botanical institutions and individuals. Significant assistance was received from the Arboretum Associates for both the survey and seed collecting.

We are now better able to define the distribution of many of these species, with several range extensions noted both from recent literature (Campbell and Reznicek, 1977) and herbarium specimens collected through this program. New species of native woody plants are also being recorded in the literature (Maycock, et al. 1980) as well as by Associates. An example of the latter is the discovery of Quercus shumardii Buckl. in Essex Co. by Gerald E. Waldron. The identity of the specimens was subsequently verified and additional stands of this species were located.

With this accumulating data, it is clear that certain species have a very restricted distribution in Ontario and are potentially endangered. Two such species, Gymnocladus dioica (L.) K. Koch and Fraxinus quadrangulata Michx., were selected for detailed study during 1981. Status reports will be prepared for the Committee on the Status of Endangered Wildlife in Canada. If these reports indicate a level of endangerment warranting official designation, then these species, and their habitats, will be afforded protection under the Endangered Species Act of Ontario.

During the past two springs, the Gene Bank was prepared for later planting of lots of rare tree seedlings. A shelterbelt and blocks of intolerant nurse crop trees were established for later inter-planting with the tolerant rare species. In addition, a small plantation of Black Walnut (Juglans nigra L.) was established, according to the ministry recommendations (Johnson, 1979), inter-planted with White Pine (Pinus strobus L.).

The plantation represents 42 collection sites throughout Ontario, received as a duplicate set of seedlings from the Petawawa Forest Experiment Station (Calvert, 1976).

With the recognized significance of regional rarity, and the need to conserve forest gene resources for future economic utilization, arboreta and botanical gardens often represent ideal coordinating institutions for such programs as this. Appropriate staff are present, contacts with the interested public are established, and land is available for long term commitments.

## ACKNOWLEDGEMENTS

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# AMÉLIORATION DES ARBRES FORESTIERS AU SERVICE DE LA RECHERCHE FORESTIÈRE DU MINISTÈRE DE L'ÉNERGIE ET DES RESSOURCES DU QUÉBEC

R. Beaudoin, A. Stipanicic et G. Vallée

*Ministère de l'Énergie et des Ressources*
*Complexe scientifique*
*Sainte-Foy, Québec*
*G1P 3W8*

## PROJET G 68-1. SÉLECTION DE CLONES ET AMÉLIORATION DU PEUPLIER (POPULUS L.), PAR G. VALLÉE

Mots-clés: Populus L., test de provenances, test clonal, sélection de clones, croisements, introduction.

### Plantations comparatives

Les tests clonaux de 3e génération ont débutés en 1979 pour comparer les nouveaux clones de la collection avec les meilleurs des tests clonaux de la 2e génération. En 1979 et 1980, deux dispositifs ont été établis, dont l'un a été conçu pour fournir des informations sur le potentiel de production en biomasse des clones comparés.

Un test clonal spécifique a été réalisé avec 76 clones de Populus nigra L. afin d'identifier les clones les mieux adaptés et les plus productifs pour, par la suite, les utiliser comme géniteurs dans les croisements. P. nigra est particulièrement résistant à la rouille Melampsora medusae Thum. très fréquente au Québec, d'où l'intérêt d'utiliser P. nigra dans les hybridations, sans compter aussi sa bonne aptitude au bouturage.

D'ailleurs, dans le but d'identifier des bonnes sources de gênes de P. nigra L., un test de provenances-descendances a été entrepris avec l'installation de deux dispositifs dans les régions de Québec et Montréal comprenant respectivement 27 et 18 descendances-provenances représentées par 6281 et 3894 plants. Les plants d'un troisième dispositif ont été donnés sur une base d'échange au Ministère des Ressources naturelles de l'Ontario (aux soins du Dr Zsuffa), afin d'exploiter au maximum ce matériel génétique.

Enfin, la plantation en 1980 de 1887 plants représentant 16 provenances a complété le test de provenances, entrepris en 1976, sur P. trichocarpa Torr. et Gray.

Croisements

Durant l'hiver 1980, 72 croisements intra et inter-spécifiques ont été faits en utilisant 21 géniteurs choisis en général parmi les meilleurs clones ou familles des plantations comparatives des arboretums de Villeroy et Lotbinière. Seulement 12 croisements ont donné 2 493 semis représentant les hybrides suivants:

| | |
|---|---|
| P. balsamifera | × P. nigra |
| P. × jackii | × P. nigra |
| P. × jackii | × P. deltoides (et le réciproque) |
| P. × jackii | × P. × jackii |
| P. × euramericana | × P. × jackii |
| P. × euramericana | × P. nigra |

Récolte de semences

Dans le but de compléter l'échantillonnage génétique de l'aire de distribution au Québec du P. deltoides Marsh., les semences de trente-cinq descendances-provenances ont été récoltées particulièrement dans la vallée de l'Outaouais et dans les régions du sud de Montréal et des Cantons-de-l'Est. Des semences de cette récolte ont été expédiées en Ontario et en Chine.

Étude particulière

Dans un test de provenances-descendances de P. deltoides Marsh. de la vallée du Saint-Laurent âgé de 10 ans et établi au populetum de Villeroy par le Service de la recherche forestière, une étude de certaines caractéristiques du bois des arbres a été effectuée par monsieur Marco Delucchi (1981) sous la direction du professeur Jean Poliquin de la Faculté de Foresterie et Géodésie de l'université Laval. Les résultats très intéressants de cette étude seront publiés.

Salix spp.

Deux tests de 26 clones de Salix spp. ont été établis, dont l'un en mélange ligne par ligne avec l'aulne glutineux (Alnus glutinosa Gaertn.) pour la sélection de clones aptes à la production de biomasse, l'aulne faisant office de fixateur d'azote.

## AMÉLIORATION GÉNÉTIQUE ET HYBRIDATION DES AULNES, PAR GILLES VALLÉE

Mots-Clés: Alnus L., tests de provenances et descendances, hybridations.

Les aulnes sont des espèces qui présentent un fort potentiel pour la production de biomasse en plantation pure ou en mélange avec d'autres espèces. En particulier, l'aulne glutineux, espèce introduite depuis 1970 dans les arboreta du Service de la recherche forestière, montre un

comportement très intéressant pour l'enrichissement des taillis naturels. Planté immédiatement après coupe à blanc, des plants d'aulne glutineux de ± 1 m de hauteur réussissent à croître au même rythme que la régénération naturelle, y compris les rejets et les drageons, sans nécessité de dégagement.

Plantations comparatives

Les 28 plantations comparatives faites dans les arboretums comprennent des tests de provenances sur Alnus glutinosa (13 provenances) et Alnus incana var. rugosa (Du Roi) Spreng. (17 provenances) et un test de 45 descendances demi-fratries d'arbres sélectionnés dans les meilleures provenances d'aulne glutineux. Cinq ans après plantation, la meilleure provenance à l'arboretum de Lotbinière est celle du verger à graine d'Ostpreussen de la République fédérale d'Allemagne, avec une hauteur moyenne de 3,12 m.

Croisements

En 1979, 31 croisements A. glutinosa × A. incana var. rugosa ont été réalisés sur les arbres en plantation à l'arboretum de Lotbinière (tableau 1). De ce nombre, 20 croisements ont produits 605 hybrides qui sont plantés maintenant en comparaison avec des aulnes glutineux descendant des mêmes arbres-mères.

Dans ces croisements, la pollinisation a été faite avec du pollen de 2 arbres-pères de provenances différentes (Sorel et Villeroy). Deux croisements (n° 3388 et 3389) Alnus incana var. incana × Alnus incana var. rugosa ont été aussi réalisés et ont produits un nombre équivalent de descendants, soit 20 et 25, pour un total de 45. On remarquera au tableau 1 que certains arbres-mères A. glutinosa montrent une plus grande aptitude à l'hybridation avec A. incana var. rugosa, en particulier 462-4 (croisements 3360, 3361), 161-16 (3393, 3394) et 160-18 (3399, 3400). De plus, pour les croisements 3360 et 3393, il faut noter le nombre beaucoup plus grand de descendants obtenus avec A. incana var. rugosa de Sorel par rapport à celui de Villeroy, ce qui laisse entrevoir une aptitude préférentielle à l'hybridation entre les arbres parents impliqués.

Durant l'hiver 1980-81 vingt et un croisements A. glutinosa × A. incana var. rugosa, 5 croisements A. incana var. incana × A. incana var. rugosa, 6 croisements A. glutinosa × Betula papyrifera et 2 croisements A. var. incana × Betula papyrifera ont été réalisés en serre sur des rameaux floraux greffés en bouteille. Les croisements A. glutinosa × Betula papyrifera ont produits des fruits mais il est trop tôt, au moment de cet écrit, pour présager de la fertilité des semences.

Propagation végétative

Des semis hybrides A. glutinosa × A. incana var. rugosa ont été soumis à des essais de bouturage à partir de boutures herbacées mononodales enracinées sous mist. Des taux de reprises de l'ordre de 90 p. 100 laissent entrevoir la possibilité de réaliser des sélections clonales de façon à obtenir le maximum de gain génétique.

Tableau 1. Liste des croisements Alnus glutinosa × Alnus incana var. rugosa et nombre de descendants obtenus

| n° croisement | n° arbre, provenance × provenance | nombre de descendants |
|---|---|---|
| 3352 | 510 - 1, Allemagne, Oberbayern × Villeroy | 1 |
| 3353 | 510 - 19, Allemagne, Oberbayern × Sorel | 1 |
| 3354 | 510 - 2, Allemagne, Oberbayern × Sorel | 0 |
| 3355 | 510 - 2, Allemagne, Oberbayern × Villeroy | 2 |
| 3356 | 161 - 3, Suisse, Zugerberg × P.L.[1] | 12 |
| 3357 | 161 - 3, Suisse, Zugerberg × Sorel | 0 |
| 3358 | 161 - 3, Suisse, Zugerberg × Villeroy | 0 |
| 3359 | 462 - 4, Hongrie, Sellye × P.L. | 26 |
| 3360 | 462 - 4, Hongrie, Sellye × Sorel | 163 |
| 3361 | 462 - 4, Hongrie, Sellye × Villeroy | 28 |
| 3362 | 511 - 5, Allemagne, Ostpreussen × P.L. | 80 |
| 3363 | 511 - 5, Allemagne, Ostpreussen × Sorel | 1 |
| 3364 | 511 - 5, Allemagne, Ostpreussen × Villeroy | 3 |
| 3365 | 511 - 6, Allemagne, Ostpreussen × P.L. | 1 |
| 3366 | 511 - 6, Allemagne, Ostpreussen × Sorel | 0 |
| 3367 | 511 - 6, Allemagne, Ostpreussen × Villeroy | 0 |
| 3368 | 511 - 7, Allemagne, Ostpreussen × P.L. | + 100 |
| 3369 | 511 - 7, Allemagne, Ostpreussen × Sorel | 10 |
| 3370 | 511 - 7, Allemagne, Ostpreussen × Villeroy | 3 |
| 3371 | 462 - 8, Hongrie, Sellye × P.L. | + 100 |
| 3372 | 462 - 8, Hongrie, Sellye × Sorel | 2 |
| 3373 | 462 - 8, Hongrie, Sellye × Villeroy | 4 |
| 3374 | 462 - 9, Hongrie, Sellye × P.L. | + 100 |
| 3375 | 462 - 9, Hongrie, Sellye × Sorel | 0 |
| 3376 | 462 - 9, Hongrie, Sellye × Villeroy | 3 |
| 3377 | 462 - 10, Hongrie, Sellye × P.L. | 40 |
| 3378 | 462 - 10, Hongrie, Sellye × Sorel | 2 |
| 3379 | 462 - 10, Hongrie, Sellye × Villeroy | 0 |
| 3380 | 431 - 11, Hongrie, Novajidrany × P.L. | + 100 |
| 3381 | 431 - 11, Hongrie, Novajidrany × Sorel | 2 |
| 3382 | 431 - 11, Hongrie, Novajidrany × Villeroy | 2 |
| 3383 | 161 - 12, Suisse, Zugerberg × P.L. | 65 |
| 3384 | 161 - 12, Suisse, Zugerberg × Villeroy | 0 |
| 3385 | 160 - 13, Suisse, Frick-Ag × P.L. | 31 |
| 3386 | 160 - 13, Suisse, Frick-Ag × Villeroy | 0 |
| 3387 | 512 - 14, Roumanie, Arges × P.L. | + 100 |
| 3388 | 512 - 14, Roumanie, Arges × Sorel | 20 |
| 3389 | 512 - 14, Roumanie, Arges × Villeroy | 25 |
| 3390 | 431 - 15, Hongrie, Novayidrany × P.L. | 45 |

[1] P.L.: Pollinisation libre.

Tableau 1 (suite)

| n° croisement | n° arbre, provenance × provenance | | nombre de descendants |
|---|---|---|---|
| 3391 | 431 - 15, Hongrie, Novayidrany | × Villeroy | 0 |
| 3392 | 161 - 16, Suisse, Zugerberg | × P.L. | + 100 |
| 3393 | 161 - 16, Suisse, Zugerberg | × Sorel | 80 |
| 3394 | 161 - 16, Suisse, Zugerberg | × Villeroy | 10 |
| 3395 | 161 - 17, Suisse, Zugerberg | × P.L. | + 100 |
| 3396 | 161 - 17, Suisse, Zugerberg | × Sorel | 0 |
| 3397 | 161 - 17, Suisse, Zugerberg | × Villeroy | 3 |
| 3398 | 160 - 18, Suisse, Frick-Ag | × P.L. | + 100 |
| 3399 | 160 - 18, Suisse, Frick-Ag | × Sorel | 13 |
| 3400 | 160 - 18, Suisse, Frick-Ag | × Villeroy | 34 |

## PROJET G 79-1. AMÉLIORATION DE L'ÉPINETTE NOIRE

PAR G. VALLÉE

Mots-clés: étude de populations, densité basale.

### Travaux réalisés en 1979 et 1980

Dans un secteur d'amélioration du nord-ouest du Québec situé entre les longitudes 77°O et 79°30'O et entre les latitudes 48°N et 49°N, vingt-deux peuplements d'épinette noire ont été localisés avec une distribution la plus uniforme possible sur ce territoire. Dans chaque peuplement 10 arbres, espacés d'au moins 100 m, ont été sélectionnés dans le but de les utiliser comme géniteurs dans un verger à graines et pour réaliser des études génétiques.

Deux campagnes de greffage des arbres sélectionnés ont eu lieu au printemps 1979 et 1980 avec très peu de succès.

Durant l'été 1980, deux carottes ont été prélevées, à l'aide d'une sonde Pressler de 10 mm de diamètre, du côté sud et du côté nord des troncs de chaque arbre sélectionné (220 au total), dans le but de réaliser une étude sur la densité basale et la longueur des fibres du bois. Cette étude a été faite en collaboration avec le professeur Jean Poliquin qui a supervisé les analyses et dirigé le mémoire de fin d'études de monsieur Guy Boucher, étudiant à la faculté de foresterie et géodésie de l'université Laval.

Résultats

Les premiers résultats sur 8 peuplements (Boucher 1981) montrent une différence très significative de la densité basale moyenne des peuplements après correction, par analyse de covariance, de l'influence de la largeur des cernes annuels du bois (taux de croissance radial). De plus, il y a une relation très significative entre la densité basale du bois juvénile (0 à 10 ans) et celle du bois adulte ($r = 0,72$) et il n'y a pas de différence significative entre les côtés nord et sud des troncs.

La densité basale moyenne des 8 peuplements varie de 0,399 à 0,452 du côté nord des troncs avec une moyenne de 0,427. Ces variations équivalent à une différence de 13,3 p. 100 entre le peuplement ayant la densité la plus élevée et celui ayant la plus faible, et de 8,3 p. 100 par rapport à la moyenne des 8 peuplements. Les différences de densité basale entre les arbres d'un même peuplement sont beaucoup plus faibles (± 0,01) en général et ne semblent pas favorables à une sélection individuelle.

En conclusion, les différences de densité basale entre les 8 peuplements suggèrent de faire un choix des populations dans lesquelles sera effectuée la sélection d'arbres-plus pour la réalisation de vergers à graines. Il faut espérer que les données provenant des 14 autres peuplements étudiés confirmeront ce résultat qui a un impact direct sur les gains de production en fibres, vu que l'épinette noire intéresse particulièrement l'industrie des pâtes et papiers. Un rapport détaillé sera produit sur cette étude.

## PROJET G 70-3 AMÉLIORATION DU MÉLÈZE (LARIX, Mill.) par A. STIPANICIC

Mots-clés: Larix, Mill., test de provenances, test de descendances, sélection des arbres, croisements, introduction.

Les travaux concernant le projet d'amélioration du mélèze ont été poursuivis durant les deux dernières années avec la même intensité qu'au cours des années précédentes. Nous avons concentré nos efforts sur L. decidua et L. leptolepis pour lesquels nous pouvons exploiter une bonne réserve de matériel génétique dans les plantations déjà existantes, mais nous avons aussi continué les travaux avec L. laricina, dont l'importance pour nos forêts boréales est indéniable. Notre Service a collaboré avec le professeur Jean Poliquin à la réalisation d'une étude sur les qualités physico-mécaniques des bois des mélèzes d'Europe, du Japon et laricin, réalisé par A. Verville (1980) au Département d'exploitation et utilisation des bois de l'université Laval. Les résultats de ce travail montrent que ces mélèzes, en plantation de 20 à 25 ans, ont une densité basale et une résistance mécanique comparables à l'épinette noire en peuplement naturel, ce qui laisse présager une utilisation comparable pour le sciage.

Récolte des graines

Les deux dernières années n'étaient pas très bonnes au point de vue de la fructification du mélèze. Ainsi, en automne 1979, nous avons récolté seulement 220 arbres de mélèze laricin dans 24 peuplements à travers le Québec.

Plantations expérimentales

En janvier 1980, nous avons mis en marche une expérience comprenant plus de 400 descendances de mélèze laricin. Ce matériel représente une grande partie de l'aire de distribution du L. laricina au Québec et il nous servira pour la formation d'un test de descendances-provenances. L'ensemencement a été fait en serre dans des contenants; au mois de juin, nous avons transplanté les semis dans la pépinière et nous prévoyons les sortir sur le terrain au printemps 1982.

Au printemps 1980, nous avons installé 5 tests de provenances comprenant trois provenances de mélèze d'Europe et neuf provenances de mélèze du Japon. Les graines pour cette expérience, reçues du Service de la restauration, ont été récoltées dans des plantations connues au Québec et le but de l'expérience est de vérifier la qualité de ces plantations comme sources de graines.

Les plants obtenus à partir de 51 lots de graines provenant d'un parc à clones de mélèze en Finlande et pouvant donné des hybrides, nous ont servi à installer un autre test de descendances au printemps 1981. Ce dispositif nous permettra de comparer différents hybrides dont l'arbre-mère était le plus souvent L. sibirica. Le comportement de certains de ces hybrides était très satisfaisant au niveau de la pépinière: l'accroissement moyen était de 50 cm en 2 ans et les familles démontraient une résistance prononcée au froid.

Vergers à graines et parc à clone

En collaboration avec l'Institut National de Foresterie de Petawawa et la compagnie C.I.P. ltée, nous avons continué la sélection des arbres de L. decidua dans la plantation «Avoca» à la Station forestière de Harrington. En nous basant sur l'analyse faite en 1977 par l'I.N.F.P., nous voulons mettre sur pied un verger à graines clonal qui va réunir les meilleures provenances (de Pologne et des Sudètes) représentées dans cette expérience. Au total, 100 arbres ont été sélectionnés dans la plantation «Avoca» et dans une plantation de Petawawa réalisée avec le même matériel que celle de Harrington.

Dans l'arboretum de Lotbinière, nous avons installé un autre verger à graines clonal qui contient 76 clones de L. leptolepis sélectionnés dans une plantation de Harrington. Dans chacune des dix répétitions de cette expérience, nous avons inclus un clone de L. decidua, en espérant obtenir l'hybride L. × eurolepis. Ce verger n'est pas encore complété et nous comptons reproduire les ramets des clones sélectionnés par greffage ou bouturage au cours des deux prochaines années.

Nous avons continué à augmenter notre collection de clones. Présentement, dans le parc à clones de la Station Forestière de Duchesnay, nous avons réuni 100 clones de L. laricina, 100 clones de L. decidua, 75 clones de L. leptolepis, 20 clones de L. × eurolepis, 1 clone de L. sibirica et 2 clones de L. dahurica. Malheureusement, la floraison de ces clones n'était pas suffisamment abondante jusqu'à présent pour nous permettre de procéder à des essais de pollinisation contrôlée.

## PROJET G 74-1 AMÉLIORATION DU PIN GRIS (PINUS BANKSIANA LAMB.), PAR R. BEAUDOIN

Mots-clés: Pinus banksiana Lamb., parc à clones, test de descendances, densité basale, population, sélection individuelle.

### Tests de descendances

Dans le cadre du programme de recherche sur l'amélioration du pin gris, un test additionnel de provenances-descendances a été réalisé en 1980 dans le canton de Céloron (latitude 49°04' nord, longitude 78°32' ouest) afin d'obtenir de la graine de qualité supérieure pour les reboisements du nord-ouest québécois. Ces quelque 235 lots de graines provenant d'arbres sélectionnés avaient été établis en 1979 sur une station argileuse dans un canton voisin. Avec ce test, le comportement des mêmes provenances-descendances sera étudié sur un sol sableux. Le potentiel de croissance ou l'expression du bagage génétique de chaque provenance ou descendance sera ainsi en relation avec la qualité de la station et l'aptitude de chaque provenance ou descendance à utiliser au maximum chaque saison de croissance.

Dix-huit descendances de la provenance Mattawin ont été installées à Cabano en 1980 (lat. 47°30' N., long. 69°03' O.). Les cônes avaient été récoltés sur des arbres de très belle venue (moyenne de 50 arbres sélectionnés, hauteur 24,8 m, d.h.p. 33,8 cm, âge 95 ans. Ce test a été effectué dans l'optique de suppléer à la faible qualité des populations locales de pin gris comme source d'approvisionnement en semences pour les reboisements de cette région de l'Est du Québec.

### Provenance Baskatong

Un parc à clones a été implanté à l'arboretum de Lotbinière (lat. 46°30' N., long. 71°55' O.) en 1980. Quelque 174 clones totalisant 487 ramets provenant du greffage des arbres sélectionnés de la provenance Baskatong y sont représentés.

L'étude de cette provenance montre que les différences de densité basale entre les arbres sélectionnés d'un même peuplement sont assez fortes. La densité du bois juvénile (0 à 10 ans) et celle du bois adulte

(25 à 35 ans) au niveau du d.h.p. varient respectivement de 0,42 à 0,32 et 0,54 à 0,39. Cette variation de la densité basale et sa forte héritabilité incitent à pratiquer une sélection individuelle pour ce caractère afin d'augmenter la production en fibres même si actuellement la majorité des arbres récoltés sont destinés au sciage.

La densité basale du bois juvénile est en relation très significative avec celle du bois adulte au niveau du d.h.p. Le coefficient de corrélation pour l'analyse de 88 échantillons est de 0,32. La sélection pour ce caractère peut donc se faire en bas âge.

L'analyse de la densité basale moyenne du bois juvénile de 88 arbres à deux niveaux du fût indique que celle-ci est similaire au d.h.p. et à 13,56 m du sol (d = 0,38). De plus, il y a une relation très significative entre les densités du bois pour des échantillons prélevés à ces deux endroits (r = 0,65). Un rapport détaillé sera produit sur l'étude des arbres sélectionnés de cette provenance.

## PROJET G 77-1. TESTS DE PROVENANCES SUR LE PIN DE MURRAY (PINUS CONTORTA DOUGL. VAR. LATIFOLIA ENGELM.)

PAR R. BEAUDOIN

Mots-clés: Pinus contorta Dougl. var. latifolia Engelm., introduction, test de provenances.

### Matériel

Vu l'importance de cette espèce sur le plan rendement dans des conditions de croissance semblables à celles du Québec, le Service de la recherche forestière a cherché à exploiter au maximum le matériel (semis) qui lui était offert par d'autres organismes et à utiliser les lots de graines accumulées dans sa banque de semence (collection I.U.F.R.O.).

### Observation en pépinière

À l'automne 79 et au printemps 80, des observations portant sur la couleur des aiguilles, les dégâts de gel, la pousse d'août et la hauteur des plants, ont été faites à la pépinière de Duchesnay sur les 134 provenances semées en 1977. Les provenances de Californie avaient un taux élevé de pousses d'août (80 à 90 pour cent des semis) et certaines d'entre-elles présentaient des dégâts de gel.

### Plantations comparatives

L'installation des dispositifs expérimentaux a été effectuée en 1980 dans 9 arboretums situés à l'extérieur de l'aire principale de distribution de Pinus banksiana (dans l'est du Québec, en Gaspésie, aux Îles-de-la-Madeleine et au sud du fleuve Saint-Laurent), à cause de la sensibilité de Pinus contorta à la rouille Cronartium comptoniae.

Par la sélection des meilleurs individus parmi les provenances les plus intéressantes, nous espérons constituer des vergers à graines et faire que cette espèce pourra être une option valable pour les reboisements au Québec.

Le comportement, sur les plans croissance et forme, de trois provenances de Colombie-Britannique de Pinus contorta var. latifolia (Beaver Creek, Reid Lake, Cariboo), installées en 1972 à l'arboretum de Matapédia, est très prometteur. Ce matériel (semis 2-3) avait été reçu de la pépinière de Berthierville par l'entremise de monsieur Yves Lamontagne. La hauteur totale des meilleurs sujets, après 10 ans de croissance à partir de la plantation, est de 4 mètres.

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# RECOLTE DE CONES ET AMELIORATION DES ARBRES PAR LE SERVICE DE LA RESTAURATION DU MINISTERE DE L'ENERGIE ET DES RESSOURCES DU QUEBEC

Yves Lamontagne

*Ministère de l'Energie et des Ressources*
*Service de la Restauration*
*200B, Ch. Ste-Foy, Québec, P.Q.*
*G1R 4X7*

Mots-clés: semences forestières, peuplement semencier, verger à graines, sélection.

Pour réaliser le programme de régénération artificielle prévu dans la politique de développement de l'industrie des pâtes et papiers, le ministère de l'Energie et des Ressources du Québec doit accentuer les efforts au niveau de la récolte des semences, afin de se constituer une réserve adéquate de toutes les essences requises dans chacune des zones où l'on prévoit de la régénération artificielle.

Environ 10 mille hectolitres de cônes sont requis annuellement pour répondre aux besoins du programme de régénération artificielle. Le service de la Restauration du ministère de l'Energie et des Ressources a mis sur pied un programme d'établissement de vergers à graines de production qui devrait permettre dans le futur, l'utilisation de semences améliorées génétiquement pour les besoins des plantations.

## RECOLTE DE CONES

Au cours de 1979, 7 123,7 hl de cônes furent cueillis alors qu'en 1980, ce volume a été porté à 10 518,0 hl (tableau 1). 1980 marque une année record pour le volume de cônes récoltés au Québec. Les deux dernières années furent semblables quant à la fructification moyenne de certaines essences comme l'épinette de Norvège, l'épinette noire, le pin gris, le pin rouge et le pin blanc.

## AMELIORATION DES ARBRES

### Peuplements semenciers

Durant les deux dernières années, des travaux ont été réalisés sur une superficie d'environ 300 ha. Les travaux ont surtout consisté à nettoyer les peuplements déjà établis, à dégager les arbres choisis comme semenciers, à tailler quelques flèches terminales et à arroser certains peuplements contre la tordeuse des bourgeons de l'épinette.

Tableau 1. Quantité de cônes récoltés, par essence, en 1979 et 1980 au Québec.

| Essence | Cônes récoltés en | |
|---|---|---|
| | 1979 | 1980 |
| | ..... hl ..... | |
| Abies balsamea | 14,4 | 0,2 |
| Larix decidua | 6,2 | 1,5 |
| Larix laricina | 64,8 | 6,6 |
| Larix leptolepis | 10,2 | 4,7 |
| Picea abies | 643,5 | 538,8 |
| Picea glauca | 154,7 | 24,2 |
| Picea mariana | 1 635,7 | 631,4 |
| Picea rubens | 154,0 | -- |
| Pinus banksiana | 3 104,4 | 5 290,8 |
| Pinus resinosa | 568,2 | 333,8 |
| Pinus strobus | 671,6 | 3 511,4 |
| Pinus sylvestris | 100,0 | 174,6 |
| Total | 7 123,7 | 10 518,0 |

Vergers à graines

Au cours des deux dernières années, l'entretien des vergers à graines déjà établis s'est poursuivi et quelques nouveaux vergers ont été établis.

Dans le canton Briand, la superficie du verger a été portée à 40 ha par l'addition de 24 ha de semis de pin gris. Un verger à graines de semis de pin gris a aussi été installé dans le canton Duvernay, sur une superficie de 12,5 ha avec des descendants de 334 arbres sélectionnés dans la région immédiate.

Avec la collaboration du Centre de recherches forestières des Laurentides, nous avons établi un verger à graines de semis d'épinette blanche avec 200 familles provenant de diverses régions de la Province. Il est situé à St-Georges-de-Beauce.

Un petit verger de semis d'épinettes noires fut installé dans le canton Normandin avec 60 descendances sélectionnées dans les environs. Egalement, 86 provenances de pin rouge furent utilisées dans un verger à graines de semis dans le même canton.

La superficie totale de vergers à graines requise pour les besoins des plantations a été évaluée à 550 ha pour la Province dont une centaine d'hectares sont déjà établis.

## Sélection d'arbres

Le programme de sélection d'arbres s'est accentué au cours des dernières années. En date d'avril 1981, 2500 arbres de diverses essences ont été sélectionnés. Ils ont été ou seront multipliés dans des vergers à graines clonaux ou de semis, de première génération, selon les espèces. Ces arbres sont sélectionnés dans les meilleurs peuplements naturels ou artificiels. Ce matériel de base sera aussi utilisé dans divers tests de descendances ou de provenances pour des améliorations futures.

# VARIABILITÉ SPATIALE ET TEMPORELLE DE LA CROISSANCE JUVÉNILE DES PROVENANCES D'ÉPINETTE NOIRE AU QUÉBEC

Armand G. Corriveau[1)]

*Centre de Recherches forestières des Laurentides*
*Service canadien des forêts*
*1080 Route du Vallon*
*C.P. 3800*
*Sainte-Foy, Québec*
*G1V 4C7*

Mots clefs: épinette noire, black spruce, Picea mariana, provenance, variation.

Plus les exploitations forestières avancent dans la forêt boréale, encouragées par la demande soutenue et l'absence d'une régénération naturelle adéquate après la coupe, et plus les essences proprement nordiques, tel le mélèze laricin (Larix laricina (Du Roi) K. Koch), le pin gris (Pinus banksiana Lamb.) et l'épinette noire (Picea mariana (Mill.) B.S.P.) prennent de l'importance dans les reboisements. Cette dernière espèce, en plus de fournir un bois de première qualité pour la pâte et le sciage, a la capacité de croître sur une gamme de sites allant des tourbières à sphaigne aux affleurements rocheux en passant par les sables peu fertiles et les argiles trop lourdes. Si elle a acquis la réputation d'essence à croissance lente, c'est qu'elle s'accommode souvent d'habitats ne permettant pas un développement rapide. Lorsqu'elle est plantée sur des sites de bonne qualité, son rendement est supérieur à celui de l'épinette rouge (Picea rubens Sarg.), trop sensible aux vents froids et dessèchement de l'hiver et comparable à celui de l'épinette blanche (Picea glauca (Moench) Voss) plus exigeante en éléments nutritifs. Sa résistance partielle à la tordeuse des bourgeons de l'épinette, étroitement liée à sa phénologie, ajoutée à ses caractéristiques spécifiques en fait l'essence numéro 1 pour le reboisement au Québec et dans tout l'est du Canada.

Des études antérieures (Khalil, 1978; Morgenstern, 1969, 1973, 1978) ont démontré qu'il existe des variations génétiques d'origine géographique importantes dans la croissance de l'épinette noire permettant d'espérer des gains substantiels par l'identification et l'utilisation de sources supérieures lors des reboisements. La rapidité d'accumulation des gains génétiques sera fortement liée à la précision avec laquelle l'améliorateur pourra identifier, à bas âge, les populations ou génotypes supérieurs. Plus hâtives et plus sûres seront les sélections et plus rapides seront les gains. Les observations précoces en pépinière permettent-elles vraiment de déceler les provenances à fort rendement chez

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1) Le lecteur est prié de se référer à Corriveau et Vallée, 1981 pour un rapport sommaire des progrès réalisés au cours des dernières années.

l'épinette noire? Quelles sont les relations entre les coordonnées géographiques du lieu d'origine et la performance des sources dans le temps, et dans divers milieux? Telles sont les questions auxquelles nous essayons de répondre dans cette étude.

## MATÉRIEL ET MÉTHODES

L'essai de provenances d'épinette noire a été initié en 1968 par l'échantillonnage génétique d'un grand nombre de populations et l'échange de semences entre les collaborateurs. Cent provenances, échelonnées sur quelque 20 degrés de latitude et 110 degrés de longitude, dont 45 du Québec, 15 des Maritimes, 24 de l'Ontario et des états américains des Grands Lacs, et, 16 sources du centre, de l'ouest canadien et de l'Alaska, furent ensemencées à la pépinière de Valcartier au printemps 1970, selon un dispositif aléatoire complet de six répétitions. A l'automne de la même année, dix semis par provenance et répétition furent choisis au hasard et mesurés quant à leur taille et poids. Un nombre égal de semis fut identifié en permanence dès l'année suivante et des mesures de croissance en hauteur furent prises au cours des trois années suivantes. Six essais de provenances furent établis en 1974 et 1975 en milieux forestiers représentatifs des grandes régions d'exploitation du Québec soit les Laurentides, l'Abitibi, la Côte-Nord, et la Gaspésie (tableau 2). Des mesures de croissance et de survie après plantation furent prélevées à l'automne 1979 dans chacun de ces essais.

Les analyses de corrélation, et de régression multiple par étape, conduites à partir des moyennes des provenances, furent utilisées pour interpréter les observations recueillies.

## RÉSULTATS ET DISCUSSIONS

### Variabilité temporelle

Les coefficients de corrélation de Pearson entre les valeurs moyennes des groupes à différents âges, nous offrent une mesure de l'efficacité des sélections précoces des provenances d'épinette noire. Le tableau 1 indique que ces coefficients sont généralement forts entre deux années consécutives en pépinière mais qu'ils s'affaiblissent proportionnellement au lapse de temps séparant les observations. La corrélation entre la taille des provenances observée en pépinière et celle observée en milieux forestiers, quatre ou cinq ans après la plantation est de faible ($.3 < r < .5$) à très faible ($r < .3$). Remarquons également que les corrélations sont généralement de signe négatif entre les croissances juvéniles observées en pépinière et celles obtenues en milieux forestiers alors qu'elles étaient positives entre les observations faites en pépinière à des âges différents. Outre le choc de transplantation plus sévère que peuvent avoir subi les provenances à croissance rapide, dû à leur plus forte taille, ce phénomène reflète sans aucun doute l'influence des conditions climatiques et édaphiques des différents milieux d'expérimentation sur l'expression du potentiel génétique des sources. Les provenances ayant démontré un fort taux de croissance dans des conditions favorables de climat et de sol de la pépi-

**Tableau 1.** Coefficients de corrélation de Pearson entre les caractéristiques de croissance juvénile des provenances d'épinette noire en pépinière et milieux forestiers[a)b)c)].

| | TEMPS | | | | | | ESPACE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_1$ | $H_2$ | $H_3$ | $H_6$ | $H_5$ | $H_4$ | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
| $L_1$ | .54 | .42 | .40 | .49 | NS | .37 | -.25 | NS | -.42 | NS | NS | -.54 |
| $L_2$ | .81 | .66 | .66 | .75 | .37 | .62 | NS | NS | -.44 | NS | -.23 | -.57 |
| $L_3$ | .53 | .43 | .42 | .40 | .23 | .39 | -.28 | NS | -.26 | NS | NS | -.37 |
| $D_1$ | .35 | NS | NS | .30 | NS | .19 | -.27 | -.27 | -.29 | NS | NS | -.54 |
| $P_1$ | .73 | .62 | .59 | .68 | .37 | .55 | NS | NS | -.43 | NS | NS | -.56 |
| $P_2$ | .77 | .66 | .64 | .72 | .39 | .60 | NS | NS | -.41 | NS | NS | -.55 |
| $P_3$ | .29 | .23 | NS | .25 | NS | NS | -.23 | NS | -.37 | NS | NS | -.45 |
| $H_1$ | 1.0 | .87 | .85 | .99 | .54 | .81 | NS | -.26 | -.52 | NS | -.33 | -.59 |
| $H_2$ | .87 | 1.0 | .97 | .88 | .89 | .91 | NS | -.24 | -.58 | .25 | -.31 | -.50 |
| $H_3$ | .85 | .97 | 1.0 | .90 | .85 | .86 | NS | -.31 | -.55 | .24 | -.33 | -.49 |
| $H_6$ | .99 | .88 | .98 | 1.0 | .55 | .81 | NS | -.28 | -.50 | NS | -.33 | -.55 |
| $H_5$ | .54 | .89 | .85 | .55 | 1.0 | .79 | NS | NS | -.50 | .31 | -.23 | -.31 |
| $H_4$ | .81 | .91 | .86 | .81 | .79 | 1.0 | NS | -.35 | -.49 | -.22 | -.32 | -.45 |

a) Statistiquement significatif à .05 pour r > .22, à .01 pour r > .28

b) Voir tableau 2 pour la définition des variables

c)

| Milieux forestiers | Latitude | Longitude | Altitude m |
|---|---|---|---|
| Mont Laurier | 46°36' | 75°48' | 230 |
| Valcartier | 46°52' | 71°32' | 180 |
| Lac St-Ignace | 49°00' | 66°20' | 430 |
| Labrieville | 49°12' | 69°33' | 490 |
| Amos | 48°40' | 78°30' | 335 |
| Chibougamau | 50°03' | 74°10' | 410 |

**Tableau 2.** Coefficients de corrélation de Pearson entre les caractéristiques de croissance des provenances d'épinette noire et les coordonnées géographiques de leur lieu d'origine[a)].

| VARIABLES | LATITUDE | LONGITUDE | ALTITUDE |
|---|---|---|---|
| A) Observations en laboratoire | | | |
| $D_1$ Diamètre au collet à 1 an | -.27 | -.34 | -.27 |
| $P_1$ Poids total à 1 an | -.58 | -.63 | -.37 |
| $P_2$ Poids de la tige à 1 an | -.63 | -.64 | -.37 |
| $P_3$ Poids des racines à 1 an | NS | -.31 | -.20 |
| $L_1$ Longueur totale à 1 an | -.43 | -.56 | -.31 |
| $L_2$ Longueur de la tige à 1 an | -.73 | -.75 | -.48 |
| $L_3$ Longueur des racines à 1 an | -.47 | -.56 | -.39 |
| B) Observations en pépinière | | | |
| $H_1$ Hauteur totale à 2 ans | -.66 | -.72 | -.42 |
| $H_2$ Hauteur totale à 3 ans | -.71 | -.51 | -.31 |
| $H_3$ Hauteur totale à 4 ans | -.70 | -.49 | -.33 |
| $H_4$ Accroissement de la 4e année | -.66 | -.45 | -.34 |
| $H_5$ Accroissement de la 3e année | -.40 | NS | NS |
| $H_6$ Accroissement de la 2e année | -.65 | -.68 | -.39 |
| C) Observations en milieux forestiers | | | |
| $S_1$ Hauteur à 10 ans à Mt Laurier | -.44 | NS | NS |
| $S_2$ Hauteur à 10 ans à Lac St-Ignace | -.35 | NS | NS |
| $S_3$ Hauteur à 10 ans à Chibougamau | -.33 | NS | NS |
| $S_4$ Hauteur à 10 ans à Valcartier | -.41 | NS | -.23 |
| $S_5$ Hauteur à 10 ans à Labrieville | -.24 | NS | NS |
| $S_6$ Hauteur à 10 ans à Amos | NS | .57 | NS |
| $C_1$ Accroissement périodique à Mt Laurier | NS | NS | NS |
| $C_2$ Accroissement périodique à Lac St-Ignace | .22 | NS | NS |
| $C_3$ Accroissement périodique à Chibougamau | .40 | .34 | .31 |
| $C_4$ Accroissement périodique à Valcartier | NS | NS | NS |
| $C_5$ Accroissement périodique à Labrieville | .35 | NS | NS |
| $C_6$ Accroissement périodique à Amos | .44 | .38 | .37 |
| $M_1$ Survie à Mt Laurier | NS | NS | NS |
| $M_2$ Survie à Lac St-Ignace | NS | NS | NS |
| $M_3$ Survie à Chibougamau | .34 | NS | NS |
| $M_4$ Survie à Valcartier | NS | NS | NS |
| $M_5$ Survie à Labrieville | .41 | NS | NS |
| $M_6$ Survie à Amos | .49 | .24 | .21 |

a) NS = Non significatif à 95%

nière sont déclassées au cours des premières années suivant la plantation, par des sources à croissance plus lente. Remarquons que la relation négative entre les hauteurs et accroissements observés en pépinière et ceux mesurés en milieux forestiers s'accentue au fur et à mesure que nous passons à des conditions environnementales plus difficiles par exemple Mont Laurier, Lac St-Ignace, Labrieville, Amos et Chibougamau, par ordre croissant de sévérité. C'est donc dire, que plus le climat et les sols des sites de reboisement sont sévères et moins la sélection précoce, effectuée en fonction d'une croissance rapide en pépinière, risque d'être efficace et plus il est nécessaire de tester les sources dans des conditions environnementales se rapprochant de celles des sites de reboisement.

Variabilité intrinsèque et spatiale

Toutes les caractéristiques de croissance juvénile des provenances d'épinette noire observées en pépinière montrent une diminution significative avec l'augmentation de la latitude, de la longitude et de l'altitude du lieu d'origine de celles-ci. L'effet d'origine est surtout marqué au cours des première, deuxième et quatrième saisons de croissance; ($r = -.7$ avec la latitude, $r = -.5$ avec la longitude et $r = -.3$ avec l'altitude) (tableau 2). L'écart noté à la 3e saison de croissance peut s'expliquer par l'effet du repiquage des semis effectué au printemps de la même année.

Les analyses de régression multiple par étape renforcent les constatations précédentes. Entre 49 et 74 pourcent de la variabilité de la hauteur totale des provenances d'épinette noire, au cours des quatre années en pépinière est expliqué par la variabilité des coordonnées géographiques du lieu d'origine des provenances tel qu'estimé par les coefficients de détermination $R^2$ (tableau 3). La latitude est de loin la variable indépendante la plus importante suivie de la longitude alors que l'altitude n'apporte une contribution significative qu'à l'accroissement obtenu la quatrième année de croissance. Le fort niveau de signification statistique des équations et des plans de régression calculés dénote l'existence d'une variation de nature clinale importante dans la croissance juvénile de l'épinette noire à travers son domaine. Une telle variation a été notée par Morgenstern (1969) à l'aide de l'analyse de variance. Nous verrons lors d'une étude ultérieure que cette tendance est beaucoup moins marquée dans l'est du domaine de l'espèce.

L'effet d'origine, indiqué par les coefficients de corrélation, sur les hauteurs des provenances observées en milieux forestiers est beaucoup plus saccadé. L'altitude seulement a alors une influence significative. A Amos, site où prévalent des conditions climatiques et édaphiques très sévères, une corrélation positive a été trouvée entre la longitude et la hauteur des provenances, quatre ans après la plantation (tableau 2). Cette relation s'étend aux deux autres variables indépendantes lorsque l'accroissement en milieux forestiers seul est considéré. Dans ces conditions sévères les sources nordiques se sont donc mieux développées que les sources plus sudistes même si les provenances n'ont pas encore atteint une taille suffisante pour subir les froids extrêmes de l'hiver et qu'entre vraiment en ligne de compte leur différentiel de rusticité. Notons qu'aux deux sites de climat continental et froid soit Amos et Chibougamau, les

Tableau 3. Régression multiple par étape de la hauteur totale et de l'accroissement annuel des provenances d'épinette noire sur les coordonnées géographiques de leur lieu d'origine à la pépinière forestière de Valcartier ($X_1$ = latitude, $X_2$ = longitude, $X_3$ = altitude)

| ÂGE | RÉGRESSION MULTIPLE[a] | $R^2$ |
|---|---|---|
| A) Hauteur totale | | |
| 1 an | $Y = 3.41 - .0214X_1 - .0066X_2$ | .62 |
| 2 ans | $Y = 24.47 - .343X_1$ | .74 |
| 3 ans | $Y = 42.82 - .511X_1$ | .50 |
| 4 ans | $Y = 93.13 - 1.144X_1$ | .49 |
| B) Accroissement annuel | | |
| 1° saison | $Y = 3.41 - .0214X_1 - .0066X_2$ | .62 |
| 2° saison | $Y = 20.52 - .300X_1$ | .72 |
| 3° saison | $Y = 20.89 - .268X_1 + .029X_2$ | .20 |
| 4° saison | $Y = 50.30 - .623X_1 - .073X_2 - .0016X_3$ | .49 |

Tableau 4. Régression multiple par étape de la hauteur totale et de l'accroissement périodique en milieux forestiers des provenances d'épinette noire sur les coordonnées géographiques de leur lieu d'origine: $X_1$ = latitude, $X_2$ = longitude, $X_3$ = altitude, Y = centimètre

| SITE | RÉGRESSION MULTIPLE[a] | $R^2$ |
|---|---|---|
| A) Hauteur totale à 10 ans | | |
| Valcartier | $Y = 139.2 - .0152X_1 + .0017X_2$ | .21 |
| Mont Laurier | $Y = 143.0 - .0223X_1 + .0042X_2$ | .58 |
| Lac St-Ignace | $Y = 80.2 - .0072X_1 + .00077X_2$ | .15 |
| Labrieville | $Y = 90.6 - .0107X_1 + .0022X_2$ | .22 |
| Amos | $Y = 93.3 - .0145X_1 + .0043X_2$ | .81 |
| Chibougamau | $Y = 88.9 - .0112X_1 + .0024X_2$ | .39 |
| B) Accroissement périodique, 5 à 10 ans | | |
| Valcartier | $Y = 36.29 + .803X_2 - .0018X_3$ | .05 |
| Mont Laurier | $Y = 42.75 - .429X_1 + .917X_2$ | .05 |
| Lac St-Ignace | $Y = -11.22 + .755X_1 - .194X_2 - .0025X_3$ | .30 |
| Labrieville | $Y = -11.39 + .742X_1 - .118X_2 + .0018X_3$ | .19 |
| Amos | $Y = - 9.14 + .498X_1 + .0024X_3$ | .25 |
| Chibougamau | $Y = - 9.72 + .394X_1 - .0016X_3$ | .20 |

a) Les régressions multiples sont celles dont la dernière variable entrée contribue à accroître la valeur de $R^2$ par plus de 20% de sa valeur antérieure.

coefficients de corrélation sont de même signe et amplitude. Cette similitude des corrélations se présente également aux sites de climat humide et froid que sont Labrieville et Lac St-Ignace reflétant une certaine stabilité dans la réaction des sources face au climat.

Ce phénomène est moins apparent dans les plans de régression multiple de la hauteur totale des provenances en milieux forestiers sur les coordonnées géographiques de leur lieu d'origine (tableau 4). La diminution de hauteur des provenances avec l'augmentation de la latitude reflète encore la réponse des provenances aux conditions environnementales de la pépinière. Quinze à 81 pourcent de la variation en hauteur des provenances est expliqué par les plans de régression. Quant au signe positif des coefficients de régression de la variable longitude, alors que la corrélation avec la hauteur des provenances est négative, il s'explique par sa colinéarité avec la latitude, (r = .78). Cette aberration pourrait être corrigée par l'utilisation de la régression pseudo-orthogonale (Boudoux et Ung 1978) mais au prix d'une perte de quelque dix pourcent de la variation expliqué.

Les plans de régression multiple obtenus à partir des accroissements en milieux forestiers confirment les observations soulignées antérieurement, soit une grande similitude entre les résultats obtenus aux sites de conditions climatiques comparables. Ces plans indiquent de façon générale un accroissement plus rapide des provenances nordiques dans des sites de conditions climatiques plus sévères que celles de la pépinière (tableau 4).

Probablement dû au choc de transplantation et à la difficulté d'implantation des semis sur les sites d'expérimentation, les plans de régression multiple expliquent une faible fraction seulement de la variation de l'accroissement des provenances soit entre 5 et 30 pourcent. Notons que les $R^2$ les plus faibles ont été obtenus sur les sites aux conditions climatiques comparables à celles de la pépinière et aux conditions édaphiques les moins sévères. Ceci porte à croire que les pentes des plans de régression obtenus ne sont pas dues exclusivement aux caractéristiques d'adaptation des provenances mais plutôt à une relation de cause à effet entre l'origine des sources et leur facilité d'implantation sur les sites. Les sources nordiques, de taille plus petite, auraient subi un choc de transplantation moins sévère que les sources sudistes de plus forte taille et ainsi auraient repris une croissance normale plus tôt que les provenances sudistes. Cette hypothèse est appuyée par des corrélations négatives calculées à la fois entre les hauteurs des provenances au moment de la plantation et leurs accroissements subséquents ainsi qu'avec leurs taux de survie à Chibougamau (r = -.37**), Labrieville (r = -.45**) et Amos (r = -.29**).

Il semble donc qu'il faudra attendre que les plants se soient bien installés dans chacun des sites et que l'effet de plantation ait disparu avant qu'une interprétation sûre des performances démontrées en milieux forestiers puisse être faite et qu'une sélection efficace des meilleures provenances en fonction des grandes régions de reboisement puisse être effectuée.

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# AMELIORATION GENETIQUE DES ARBRES DANS LA MAURICIE

J. Bégin

*Compagnie Internationale de Papier du Canada*
*Edifice Sun Life*
*Montréal, Québec*
*H3B 2X1*

Mots-clefs: Verger clonal, verger de semis, test de descendance, test de provenance, pin gris, épinettes, mélèze japonais.

Dans la division Saint-Maurice, la recherche en amélioration génétique s'oriente vers la production hâtive d'arbres possédant de bonnes qualités papetières. On s'intéresse surtout aux essences indigènes dont le pin gris (Pinus banksiana Lamb.) et l'épinette noire (Picea mariana (Mill.) BSP) sans pour autant négliger les essences d'avenir comme le mélèze japonais (Larix leptolepis Sub. and Zucc. Gord.) et l'épinette de Norvège (Picea abies (L.) Karst).

## PIN GRIS ET EPINETTE NOIRE

Le gros du travail en amélioration porte sur les essences indigènes qui ont déjà manifesté leur adaptation à la région. Une première reconnaissance sur le terrain permet de localiser les réserves de semenciers. Ce sont le plus souvent des peuplements jeunes (20 à 50 ans pour P. banksiana et 30 à 70 ans pour P. mariana) où, de façon consistante, poussent des arbres vigoureux et de belle venue. Les plus beaux sujets sont identifiés lors d'une seconde reconnaissance et on récolte, l'hiver venu, leurs cônes et leurs greffons.

Un total de 119 tiges de P. banksiana et 50 de P. mariana ont ainsi fait l'objet d'une sélection dite "idéaliste" au cours de l'année 1980. Les semences obtenues de ces arbres serviront dans un premier temps à constituer un test de descendance. Parallèlement, on préparera en 1982 des vergers à graines où seront repiqués les semis-plus produits dans les serres de C.I.P. à Harrington. Toutefois, d'ici à ce que ces vergers commencent à fructifier, l'approvisionnement en semences viendra de peuplements choisis (réserves de semenciers) rehaussant ainsi la qualité des semis produits.

Parallèlement à la localisation et à la récolte du matériel génétique se planifie l'installation des différents vergers et tests de descendance. On compte déjà un terrain de 9 ha devant servir de test de descendance. Les autres travaux vraiment tangibles sont axés sur la reproduction asexuée des arbres-plus.

Plus de 169 arbres jugés supérieurs ont ainsi été reproduits à une moyenne de quinze "exemplaires" chacun pour former une banque clonale de 2400 ramets vivants. On se propose de repiquer ces ramets au cours de l'été prochain pour amorcer l'installation d'un verger clonal.

## MELEZE JAPONAIS

Parmi les essences exotiques susceptibles de reboiser la région du Saint-Laurent et des Grands Lacs, le mélèze japonais (L. leptolepis) compte parmi les essences les plus prometteuses. Soixante dix-neuf provenances de mélèze japonais faisant partie de l'expérience 428-B-3 ont été plantés à Batiscan près de Trois-Rivières. Chaque provenance est représentée par un total de cent semis formant dix répétitions. Cette disposition permettra de convertir le test en un verger à graines une fois les meilleures provenances connues.

L'évaluation des 79 lots de semis se fera surtout d'après leur croissance et leur résistance au froid.

## EPINETTE DE NORVEGE

Bien que susceptible aux gelées et au charençon du pin blanc (Pissodes strobi (Peck)), l'épinette de Norvège (Picea abies (L.) Karst) n'en présente pas moins un bon potentiel comme essence de reboisement. Des tests ont permis d'isoler les provenances les plus prometteuses.

De concert avec le Service Canadien des Forêts et le Centre Ecologique de Harrington, nous établirons l'an prochain un verger clonal des meilleures provenances de cette espèce. Ce verger sera situé à Ste-Angèle-de-Laval, près de Trois-Rivières.

Par ailleurs, poursuivant l'opinion émise par NIENSTAEDT (1965), nous avons implanté 50 greffons d'épinette de Norvège (P. abies) sur de jeunes gaulis d'épinette blanche (Picea glauca (Moench) Voss.). L'expérience regroupait cinq clones de P. abies (AS 81401 à AS 81405) appartenant à l'expérience 277-D-1 de la provenance Proulx, Que. (4027). Cet essai pourrait bien se poursuivre sur une quarantaine d'autres clones si les résultats s'avèrent concluants.

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# TREE IMPROVEMENT AT NEW BRUNSWICK DEPARTMENT NATURAL RESOURCES

R.D. Bettle and E.D. Stinson

*New Brunswick Department Natural Resources*
*Provincial Forest Nursery*
*Fredericton, New Brunswick*
*E3B 4X7*

Key Words: Stand test, plus tree selection, seed orchards, family test

The New Brunswick Department of Natural Resources has been involved with tree improvement work since the early 1970's. In 1974 an operational tree improvement program was initiated with the Canadian Forestry Service, Fredericton, providing much of the research and technical guidance.

The New Brunswick Tree Improvement Council was formed two years later in order to consolidate the tree improvement efforts of both government and industry (Coles 1979).

The reforestation effort of the New Brunswick Department of Natural Resources includes the outplanting of 30 million seedlings annually. At present, this involves planting 16 million black spruce, 10 million jack pine, 3 million white spruce, 1 million tamarack. Accordingly, the improvement effort has concentrated on these species. A summary of this effort follows.

## STAND TESTING

To date, 48 promising black spruce (Picea mariana (Mill.) B.S.P.) and 52 promising jack pine (Pinus banksiana Lamb.) stands have been reserved. Stand testing has been conducted for most of these stands and 5-year height measurements have been taken. Based on these measurements, a few of the best ones have been designated as seed collection stands. So far, approximately 50 Kg. of black spruce seed has been collected from designated stands.

## PLUS TREE SELECTION AND BREEDING

To date, 261 black spruce and 301 jack pine have been selected. Open pollinated families from these selected trees will be used for seedling orchards. Also, 40 white spruce (Picea glauca (Moench) Voss) and 24 tamarack (Larix Laricina (Du Roi) K Koch) superior individuals have been

selected for use in clonal orchards. Some of the grafted material will be outplanted in hedges in order to provide sufficient numbers of scions for all Council members wishing to put in an orchard.

## ORCHARD ESTABLISHMENT AND FAMILY TEST

To date, 13 hectares of black spruce, 5 hectares of jack pine, 8 hectares of Ottawa Valley white spruce, and 2 hectares of tamarack seedling orchard have been outplanted. Corresponding family tests have been outplanted by the various Council members throughout each species planting range with the exception of tamarack for which no family testing was conducted. Plans for 1981 include outplanting of an additional 4 hectares of black spruce and 3.5 hectares of jack pine seedling orchard.

Forty (40) hectares have been reserved for white spruce and tamarack clonal orchard. Outplanting will begin in 1982 with a small area of 1 to 2 hectares.

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Coles, J.F. 1979 New Brunswick Tree Improvement Council makes impressive strides. For. Chron. 55(1): 32-33.

# TREE BREEDING AT THE MARITIMES FOREST RESEARCH CENTRE, 1979 AND 1980

D.P. Fowler, J.M. Bonga, J.F. Coles, Y.S. Park and R.F. Smith

*Maritimes Forest Research Centre*
*Canadian Forestry Service*
*Fredericton, New Brunswick*
*E3B 5P7*

Key words: population studies, provenance tests, species hybridization, applied tree improvement, tissue and organ culture, Picea, Larix.

It is estimated that almost 100 million trees will be planted annually in the Maritimes by 1987. An opportunity exists to substantially increase forest growth in the Region by utilizing genetically superior seeds and seedlings in these reforestation programs. The objectives of the tree breeding work at the Maritimes Forest Research Centre (MFRC) are to determine the amount of genetic improvement attainable within promising tree genera and to provide resource managers of the Region with the information and breeding materials required to obtain a realistic genetic improvement.

## HYBRIDIZATION IN PICEA AND LARIX

Interspecific crossing work was continued in 1979 and 1980. In 1979, a total of 268 tree x pollen combinations was attempted using white spruce (Picea glauca (Moench) Voss.) black spruce (P. mariana (Mill.) B.S.P.) red spruce (P. rubens Sarg.) and Norway spruce (P. abies (L.) Karst.) as female parents for crosses with white, black, Sitka (P. sitchensis (Bong.) Carr.), Brewer (P. breweriana S. Wats.), Taiwan (P. morrisonicola Hayata), and Wilson spruce (P. wilsonii Mast.). The hybrid Serbian spruce (P. omorika (Pancic) Purkyne) x black spruce was backcrossed to both parents. Of the crosses attempted, 118 were white x Sitka and yielded almost 40,000 full seeds. The cross black x Sitka which was first made successfully in 1974 was again successful in 20 of 24 attempts. Aside from the backcrosses of the Serbian x black spruce hybrid which were highly successful, the other crosses yielded only a few seedlings which as yet have not been verified as hybrids.

In 1980, 163 tree x pollen combinations were attempted using white, black, red, Norway, and blue spruce (P. pungens Engelm.) as female parents for crosses with black, Sitka, Taiwan, blue, and Oriental spruce (P. orientalis (L.) Link). The hybrid Serbian x black was crossed with Sitka and again backcrossed to black spruce. In addition, two 5-tree

diallels of black spruce were successfully completed in cooperation with University of New Brunswick graduate student T.J. Mullin. The white x Sitka crosses were again highly successful; 11 of the 14 black x Sitka crosses yielded viable seeds and all 18 crosses of (Serbian x black) x Sitka produced a few viable seeds.

During 1979 and 1980 work on vegetative propagation of selected hybrid spruces was continued with emphasis on the white x Sitka and black x Sitka hybrids. The first clonal field tests of these hybrids were planted in 1980.

Thirty selected Japanese larch (Larix leptolepis (Seib. and Zucc.) Gord.) were used as pollen parents in crosses with up to nine tester females. These materials are being used for progeny testing.

## SPECIES AND PROVENANCE TRIALS

The objective of this work is to improve forest growth in the Maritimes by determining the best adapted and productive species and the best provenance within these species for use in various locations in the Region.

A publication on provenances of Norway spruce based on evaluation of 10 provenance experiments planted in the Maritimes between 1961 and 1972 was completed. Norway spruce from eastern Poland and from mid-elevations in the Sudeten and Carpathian Mountains of southern Poland perform well when planted over a wide range of sites in central and southern New Brunswick, Prince Edward Island, and Nova Scotia. Provenances from east of the Baltic Sea, i.e., northeastern Poland, Latvia, Lithuania, western Russia, and White Russia are recommended for use in northern New Brunswick.

In the late summer of 1979, 5-year height and survival were recorded for the cooperative range-wide black spruce provenance trial. This trial is planted in 10 locations in the Maritimes with 50-100 provenances represented at each location. Preliminary evaluation of the data suggests that "best" provenances for the Maritimes can be found between latitudes 45°-47°N over a wide range of longitude extending from the east coast well into the Lake States.

## POPULATION STUDIES

In 1979, all the work on population structure was consolidated under this study. Major constituent experiments include five white spruce population structure studies; as well as other inbreeding studies and progeny tests with black spruce and tamarack (Larix laricina (Du Roi) K. Koch.). The objectives of these studies are to determine average degree of inbreeding in the natural populations of the respective species and its

effects on both quantitative and qualitative traits, and to provide assistance in development of tree improvement strategies.

A progeny test in black spruce designed to provide genetic parameters of unimproved plantations has been started. An objective of this study is to explore the possibility of converting young plantations to seed collection areas to be used until genetically improved seeds are available from seed orchards. This test includes 100 families from plantation-grown trees and 30 families from natural populations, and is field planted in three locations in New Brunswick.

Population studies of tamarack received major emphasis in 1980 in accordance with increased interest in the species among industry and tree breeders. A neighborhood inbreeding study of tamarack by means of four-subpopulation disconnected diallel crosses including selfs and disconnected factorial crosses has been analysed for percent sound seed, survival, greenhouse height, and nursery height and a manuscript was prepared. Estimates of relationship coefficient among near-neighbor (radius 22 m), mid-distance (59 m), and long-distance (135 m) trees were found to be 0.256, 0.226, and 0.112, respectively. Self pollination resulted in a significant reduction in seed set. Estimates of lethal equivalents for the selfed trees ranged from 3.0 to 19.3 with an average number of 10.8. Relatively large specific combining ability variances were obtained for early seedling heights, however, interpretation and application of the variance components were not clear because of the degree of relatedness among neighboring trees.

An open pollinated progeny test of tamarack from three local populations has been established in four locations in the Maritimes Region. This test involved 48 open-pollinated families and, at each location, four replicates of four-tree plots were field planted.

The materials for a clonal progeny test of tamarack for the 1981 field season are being propagated. This work involved production of first stage rooted cuttings from 30 seed propagated families. Within each family, 10 trees were selected, amounting to a total of 300 clones. Up to nine cuttings per clone were produced through juvenile cuttings technique. Eighty rooted cuttings per clone were produced from the first stage rooted cuttings, amounting to a total of 24,000 rooted cuttings for the experiment. The rooting success was satisfactory, but refinement of the juvenile cutting technique for mass production of material would prove useful, especially because the percentage of sound seed in the species has been very low.

## TECHNICAL ASSISTANCE PROGRAM

Operational tree improvement in the Maritimes Region is progressing rapidly with technical assistance being provided to all three provinces by the Maritimes Forest Research Centre.

Prince Edward Island has recently completed a large greenhouse-headerhouse complex, part of which is being used for tree improvement. The province has begun a program of selection in black spruce and tamarack and expects to expand to other species in the near future. In 1980, the Department of Forestry outplanted a 3 ha seedling seed orchard of black spruce from New Brunswick sources and this will be expanded with Prince Edward Island and New Brunswick sources in 1982.

The cooperative tree improvement program in Nova Scotia is working with white, red, black, and Norway spruce, and white pine (Pinus strobus L.) and will be reported separately.

The New Brunswick Tree Improvement Council's cooperative program with industry and government is continuing to concentrate on black and white spruce, jack pine (Pinus banksiana Lamb.) and tamarack. The black spruce improvement program has selected approximately 450 plus trees to date, most of which have been established in seedling seed orchards and family tests by the cooperators. About 40 ha of black spruce orchard has been established by five cooperators since 1979 and these will be expanded in subsequent years. The one small orchard established in 1978 is doing extremely well and we expect to have some flowers next year.

The jack pine program in New Brunswick was stalled during 1980 but the two orchards established in 1979 will be expanded in 1981 with seedlings from 105 additional selected families. The Council recently reported the results of 5-year measurements on our first jack pine stand test. Five stands have been designated as seed collection areas.

The white spruce and tamarack programs are expanding. It has been difficult to produce sufficient ramets to establish clonal orchards. Because of this, MFRC and New Brunswick Department of Natural Resources have established hedges to be managed for scion production and hopefully, these will produce enough material to satisfy the orchard demand.

## APPLIED TREE IMPROVEMENT PROBLEMS

Many small, but important development problems arise in conjunction with the initiation and implementation of applied tree improvement programs. Studies have been initiated to determine the effect of different thinning and fertilizer regimes upon flower production in young plantations of white and black spruce. White spruce and tamarack cone development has been monitored over the past two growing seasons in an attempt to obtain maturity indices for use in extending their effective collection periods. Preliminary work has been done on establishing a damage appraisal system for cone and seed insects. Finally, the cone/seed storage and handling techniques currently used in the Region are being studied to determine if the full potential of the crops is being realized.

## TISSUE AND ORGAN CULTURE

1) In Vitro Vegetative Propagation of Mature Conifers

Small, adventitious embryo- and shoot-like structures have been produced in bud cultures of several conifers. Their formation is stimulated by cold storage and pretreatments with EDTA and malonic acid. (Bonga 1980, 1981). So far none of the adventitious structures have developed into normal plants.

2) The Production of Homozygous Haploid Plants from Halploid Tissue Cultures of Conifers

Male and female gametophytes readily form callus in vitro. The callus of female gametophyte origin is completely haploid and remains so through many subcultures over several years. The callus from male gametophytes on the other hand is composed of haploid, diploid, triploid, and aneuploid cells. The non-haploid cells may have arisen from bi-or-tri-nucleate cells in the pollen or pollen tubes in which the nuclei have fused. If so, then the diploid cells in the callus would be homozygous diploid and, theoretically, these cells could serve as the source for the production of homozygous diploid plants. To determine the origin of the non-haploid cells, new karyological techniques are required. Some progress has been made in that direction (Bonga 1978, 1979) and efforts to perfect the techniques are in progress.

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# UPDATE OF TREE IMPROVEMENT AT FRASER INC. EDMUNDSTON, NEW BRUNSWICK

M.A. Mubareka, R.P.F.

*Fraser Inc.*
*Woodlands Department*
*Edmundston, New Brunswick*
*E3V 1S9*

Keywords:Plus tree selection, family test, seedling, seed orchard, stand test.

Fraser's tree improvement program has been directed to gradually obtaining improved stock to plant 14 million seedlings annually. Also, to fulfill Fraser's commitment as a member of the N.B. Tree Improvement Council, Fraser's objective is to supply the nursery with improved seed by the year 2000. Since late 1976, Fraser Inc. have been participating in the Council's recommended program to select and test black spruce (Picea mariana (Mill.) B.S.P.), White Spruce (Picea glauca (Moench) Voss) and tamarack (Larix lariciana (Du Roi) K. Koch).

The following report contains an update of Fraser's activities in the tree improvement field since it started in 1976/77. Activities are herein reported for the first time to the Canadian Tree Improvement Association:

## PLUS TREE SELECTION

To date, six (6) tamarack plus trees have been selected. Scions from two (2) tamaracks were collected and grafted at Acadia Forest Experiment Station near Fredericton. A total of fifty (50) white spruce plus trees were selected. Scions from forty (40) of these were grafted at Acadia. Also, a total of 169 black spruce plus trees were selected. Cones were collected from 143 of these. Twenty four (24) plus trees are banked for future selections. Two (2) plus trees were cancelled due to cone damage. Seed from black spruce plus trees have been used within the N. B. Tree Improvement program for seedling seed orchard and family test establishments since 1978.

## BLACK SPRUCE SUPERIOR STAND SELECTION

In 1977, two high quality black spruce stands were located and used for stand tests in the 1978 N.B.T.I.C. programs.

## GRAFTING OF WHITE SPRUCE SCIONS

In 1979, scions from 27 white spruce plus trees were grafted by Fraser employees. Sixty per cent (60%) of the grafts survived the first

growing season. In 1980, scions from thirteen (13) white spruce plus trees were grafted by Fraser employees. Survival rate was 40.4%.

## BLACK SPRUCE SEEDLING SEED ORCHARD ESTABLISHMENT

In 1978, a 3.8 ha site near Fraser's Forest Tree Nursery at Second Falls, N. B. was laid out and planted with seedlings from 77 plus trees selected in 1977. A total of 14,000 seedlings were planted.

Late in 1978, a new site near Plaster Rock, N. B. was selected to establish further seed orchard plantings. The site contained 20 ha of prime agricultural land.

In 1979, four (4) ha were planted with seedlings from 158 families selected throughout New Brunswick. A total of 18,000 seedlings were planted. In 1980, an additional 3.8 ha was planted with 16,700 seedlings representing 136 plus trees selected in 1979 throughout New Brunswick. During 1979 and 1980, the seed orchard sites were kept in well maintained condition.

## BLACK SPRUCE FAMILY TEST ESTABLISHMENT

In 1978, three (3) black spruce family tests were established in Green River, Kedgwick and Plaster Rock areas. The tests represented 76 families planted at the Second Falls seedling seed orchard. Each test site included 1.22 ha to contain 3,040 seedlings.

In 1979, two (2) black spruce family tests were established. The tests were located in Plaster Rock and Green River areas. Each test represented 136 families, planted with 5,440 seedlings on 3.0 ha.

In 1980, two black spruce family tests were established in additional locations on Fraser limits. The Plaster Rock family test included 125 families (4,800 seedlings on 2.5 ha) and the Green River test site was established on 2.5 ha, representing 112 families (4,480 seedlings). Test sites varied in condition and locations to cover a variety of typical planting sites on Fraser limits.

## STAND TESTS

Two (2) stand tests were established in 1978. The Green River stand test contained 3,440 black spruce seedlings, representing 43 stands, on a 1.42 ha site. The Plaster Rock stand test site contained 3,440 jack pine seedlings representing 44 stands on a 1.42 ha site. Both tests suffered 20% to 25% mortality due to drought. Dead seedlings could not be replaced.

## OTHER PROJECTS

Approximately 1,800 white spruce seedlings were repotted late 1980 to be used as root stock in a 1982 white spruce grafting program.

# 1981 TREE IMPROVEMENT PROGRESS REPORT
# J.D. IRVING, LIMITED, NEW BRUNSWICH, CANADA

Ronald G. Wasser

*Sussex Tree Nursery*
*Sussex, New Brunswick*
*E0E 1P0*

This report covers the initiation of a genetic tree improvement program and other research activities during the period 1979 - 1981. It describes the annual reforestation effort for company lands and species selected for tree improvement activities. It also describes the acquisition and development of a clonal orchard site, greenhouse propagation, cooperative efforts with the Canadian Forestry Service at Fredericton, the New Brunswick Tree Improvement Council and other associated research projects. The overall objective of all activities is to develop operational company seed orchards and related breeding strategies for the production of genetically superior reforestation nursery stock.

## REFORESTATION

During the past 25 years, more than 130 million seedlings have been successfully planted in forest plantations on Irving lands in New Brunswick. At the present time approximately 15 million seedlings are produced annually at our nurseries and outplanted on site-prepared areas. Site preparation measures are varied depending upon the harvesting residues and topography but do include tractor-drawn rollers (choppers), crushing machines, bulldozing, V plows and burning. Plantations are established at a density of about 900 seedlings per acre and all planting to date is done by hand.

The major species grown in the nurseries and outplanted on company lands are black spruce (32%), white spruce (32%), jack pine (28%) and tamarack (8%). Other species such as exotic larches, red pine, Norway spruce, red spruce and miscellaneous hardwoods are also produced and outplanted on a very small scale on selected sites.

Commercial seed collections are made annually based upon the need by species. Since J. D. Irving, Limited has older spruce plantations of known origin, cone collections occur here. Collections are made from only the most vigorous and best phenotypes in an effort to improve the genetic quality somewhat through mass selections. The collections of jack pine and tamarack are made from natural stands with emphasis on vigor and quality. Collections from plantations involve

ladders, while pine and tamarack trees are usually felled for collection. Some seed is also collected on a contract basis for sale or exchange with cooperating agencies.

## GENETIC IMPROVEMENT

Prior to the initiation of a seed orchard program, plans were activated for the genetic improvement of seed needed for nursery production. Collections were made from only the best phenotypes within a plantation of known origin or from natural stands. In addition, stands were marked and heavily thinned for the establishment of seed production areas. Seed production areas now exist for black spruce, white spruce, jack pine, tamarack and red pine.

For maximum genetic gain, a genetic tree improvement was planned and initiated in the late 1970's. The four species selected were those of major importance in reforestation activities and superior tree searches began. During 1980, a total of 44 superior trees were located and accepted for the four species involved. These trees were grafted during March 1981 in a company greenhouse at the Sussex Nursery for eventual orchard establishment. A total of 1,500 grafts were made. However, additional superior tree searches and propagation will continue until a minimum of 100 selections per species are located.

A clonal orchard site was located during 1980. This forested site is presently being harvested and land cleared, with anticipation of beginning orchard establishment in 1982. A total of 250 acres of clonal orchard is planned for the species involved. The orchard site is about 400 acres in size to permit adequate pollen isolation, and soils are sandy loam for access year round. The area is nearly level and has good cold air drainage. In addition, a small breeding orchard (clonal bank) is being sought at another location. This orchard will be used to preserve all clones used in the production orchard and to complete the controlled pollination work needed for progeny testing. Additional testing will also be possible at this site.

J. D. Irving, Limited is an active member of the New Brunswick Tree Improvement Council and participates in the establishment of cooperative family tests and seedling seed orchards involving all participants. Company plantations are also used for research efforts with the Canadian Forestry Service and University of New Brunswick. CFS and NBTIC have provided good recommendations and assistance in the initiation of the Irving program.

Cooperative efforts have also begun with the USFS-NEFES in the establishment of a loblolly x pitch pine hybrid outplanting on Irving lands in Southern New Brunswick. These efforts, in addition to working with other companies and Government agencies on superior tree exchanges, selections for budworm resistance, preservation of outstanding genotypes of miscellaneous species, etc. increase the progress made for genetic improvement. However, genetic improvement is only one phase of intensive

forest management. This, accompanied with protection from fire, insects and disease, weeding with herbicides to reduce competition and thinning, will maximize growth and final harvest from our New Brunswick forests.

# FOREST GENETICS, TREE IMPROVEMENT, AND RELATED WORK AT THE UNIVERSITY OF NEW BRUNSWICK 1979-1981

G.R. Powell and E.K. Morgenstern

*University of New Brunswick*
*Department of Forest Resources*
*Fredericton, New Brunswick*
*E3B 5A3*

With the advent of rapidly expanding reforestation programs and the formation of cooperative, industry/government tree-improvement organizations in the Atlantic Provinces, the profile of work in forest genetics, tree improvement, and seed production has been significantly raised at the University of New Brunswick. This, and the establishment of an industry-sponsored Chair in Forest Tree Improvement, has affected teaching and projects at the undergraduate level, and research by graduate students and faculty. The following is a summary of the activity in these areas during the period May 1979 to April 1981.

## THE CHAIR IN FOREST TREE IMPROVEMENT

During 1979 nine forest-based industries in New Brunswick agreed to fund for five years a Chair in Forest Tree Improvement in the Department of Forest Resources of the University of New Brunswick. E.K. Morgenstern was appointed to this position and took up his duties 1 January 1981. Research projects are being developed in close liaison with the sponsoring agencies, personnel of the Maritimes Forest Research Centre, the New Brunswick Department of Natural Resources, and other faculty members. A program of graduate courses in forest genetics and tree improvement has been developed in cooperation with D.P. Fowler, Y.S. Park and J.F. Coles, who are Honorary Research Associates of the University. It is anticipated that graduate studies to the Ph.D. level will be added to those at the M.Sc.F. and M.F. level in the near future.

## UNDERGRADUATE COURSES AND PROJECTS

All students in the Department of Forest Resources are exposed, in the second year of the B.Sc.F. program, to some of the principles upon which tree improvement is based. This is through a course 'Tree Development and Variation' given by G.R. Powell. In the third year, students whose area of concentration is Tree Biology take a 'Genetics' course in the Department of Biology. All students receive some exposure to tree improvement in Silviculture courses in their fourth year. In each of the past two years, 10 senior students have enrolled in G.R. Powell's course on 'Tree Development in Relation to Reproduction'. In that course, details of the

full cycle of seed production for the six Canadian genera of the Pinaceae are dealt with and the topics of cone analysis, seed quality and seed germination are explored through a class project. In 1979, 13 senior students took a 'Forest Genetics' course from C.M. Harrison, who held a two-year appointment in the Department (and who acquired his Ph.D. in Forest Genetics from the University of Idaho in 1980). In the past academic year E.K. Morgenstern taught a Forest Genetics course to 14 senior students.

Undergraduate students are required to write a thesis or report in their final year. In the past two years, 12 students have worked on topics related to tree improvement. Some topics arose from the students' summer work, and some students developed their own projects, while others developed topics from the literature.

Several students have made use of germinators or growth chambers in working with seeds or seedlings. Frame (1980) found that seven Ontario sources of Picea glauca (Moench) Voss seed germinated better than seven Nova Scotia sources. All seed sources benefited from stratification, but stratification for 21 days was as good as stratification for 42 days. In assessing maturity of seed on six P. glauca trees growing in northern Nova Scotia, Oxenham (1981) found that the numbers of full seeds per cone increased between 3 and 10 August but then varied little through to the final collection 14 September. Seeds extracted immediately after cone collection germinated better than those extracted after the cones had been subjected to cold-air or shack-air storage. Stratification of the seeds for 21 days increased rate of germination but not percentage germination. Eddy (1980) found that heavier seeds from individual trees of black spruce (Picea mariana [Mill.] B.S.P.) and Scots pine (Pinus sylvestris L.) produced seedlings, at four harvest dates up to 72 days, with longer hypocotyls, a greater number of cotyledons and a greater dry-root mass. Seedlings of P. mariana from two lowland and two upland sites in the Thunder Bay area of Ontario were grown for ten weeks on peat and on sand by Trueland (1980). Seedlings of one of the lowland sites grew considerably better on peat, and somewhat poorer on sand than did those of the other sites. The small sample and differences in seed weight, however, call for a cautious interpretation of these results.

Mifflin (1981), after working for D.P. Fowler (Maritimes Forest Research Centre), wrote on hybridization between P. mariana and Picea sitchensis (Bong.) Carr. She showed that first-year seedlings of the hybrid were intermediate between those of the parents in number of cotyledons and in height growth. However, the hybrid showed heterosis for height growth in the statistical sense because it exceeded the mid-parent value.

According to data of D.P. Fowler, the seed yield per cone of Larix laricina (Du Roi) K. Koch in New Brunswick in 1979 was abnormally low. Patch (1980), using Eriksson's (1970) hypothesis, showed that abnormally warm temperatures in late January 1979, followed by very low temperatures in mid February, could have been responsible for the low seed set.

Stewart (1980) investigated crown development and cone bearing

in a series of ages of young Pinus banksiana Lamb. trees. He found that initial seed-cone production occurred two years after planting, whereas initial pollen-cone production occurred four years after planting. Cone production generally increased with age and had no apparent detrimental effect on vigor of shoot growth or numbers of branches.

The specific gravity of the wood of discs from different levels in the stem, and of discs and cores from breast height, of 20 P. glauca trees was investigated by Caron (1980). He determined that, in comparison with breast-height discs, cores underestimated specific gravity by 3%, and that the specific gravity of the whole tree could be estimated from two cores at breast height with a coefficient of determination of 0.74. In a study of the specific gravity of 180 comparison and plus trees of P. glauca and Picea rubens Sarg. from Nova Scotia, Birkett (1980) found that nearly half of the plus trees exceeded the mean values of the pair of comparison trees. There was also a difference in specific gravity among seed zones in P. rubens but not in P. glauca which had fewer samples.

Survival and height growth at five years of stock produced from 25 New Brunswick populations of P. banksiana and planted at five sites in the Province were examined by Cherry (1981). Significant differences in performance were apparent and preliminary recommendations were made regarding use of seed from the parent stands.

Ideas for a tree improvement program for Newfoundland were developed by Kelly (1980), and Stocker (1981) wrote on the use of genetics in controlling the spruce budworm (Choristoneura fumiferana [Clem.]), e.g. by changing chromosomes through radiation.

## SEED AND CONE PRODUCTION BY YOUNG BLACK SPRUCE

An intensive study of the intrinsic patterns and morphogenesis of the cone and seed production processes in young black spruce trees was begun by G.R. Powell in 1980. The aims of the study, which relate to the use of seedling seed orchards and to stimulation of cone production, are to determine

1. the nature of the build-up of numbers of seed cones and pollen cones borne as plantation-grown trees progress through their first 13 years;
2. the nature of within-crown patterns of production of seed cones and pollen cones, and the relationships between these patterns and those of vegetative development;
3. the precise phenology and morphogenesis of buds, cones and seeds;
4. the effects of variations in site on cone production; and
5. the effects of quantity of cone bearing in one year on that of the subsequent year.

The study has largely been funded through the New Brunswick Tree Improvement Council. A graduate student, Guy E. Caron, received a Bradfield Graduate Fellowship from Noranda, through Fraser Inc., specifically

to work on this project. Most of the field work is being conducted in plantations between 4 and 13 years of age located on J.D. Irving lands in northwestern New Brunswick. The Irving company is also providing much on-site assistance.

The older plantations being used bore cones heavily in 1980 and a large quantity of data was acquired and more data will be gathered in 1981 when a poorer cone crop is anticipated. Preliminary analyses of the 1980 data have shown that by 6 years from planting, about 60% of the trees bore seed cones, but only 21% bore pollen cones. Corresponding percentages at 8 years from planting were 93 and 60. At 10 years from planting, over 90% of the trees bore both seed cones and pollen cones. The proportion of the crown which bore cones increased with age of the tree. At 6 years from planting, cones were borne only on the upper two ages of branches whereas by 12 years from planting, seed cones were borne on the upper three ages of branches and pollen cones on the upper nine ages of branches. The numbers of seed cones borne per tree increased substantially between ages 6 and 8 years from planting, and then rose slowly. The numbers of pollen cones per tree were low for trees of both 6 and 8 years from planting and then increased greatly.

Pollen-cone and seed-cone buds burst about 2 weeks before vegetative buds. Pollen-cone growth was rapid and culminated with pollen shedding about 2 weeks after pollen-cone buds had burst. By that time seed cones were fully receptive. Seed-cone closure occurred within about 9 days from full receptivity and was followed immediately by seed-cone inversion. Seed cones reached their full size by early August, about 8 weeks after pollination. At that time shoot elongation had been completed and buds were growing rapidly. Samples of buds and cones at all stages of development were collected for laboratory analyses.

Young plantations of black spruce in northwestern, northeastern and central New Brunswick were used in a study by another graduate student, J. Dale Simpson, of some effects of site features on cone production (Simpson 1981). A total of 300 trees was examined and it was determined that a greater proportion of trees growing on south aspects produced pollen cones and seed cones than trees growing on north aspects. Trees on south aspects (and level sites) produced 2 to 5 times more pollen cones and seed cones than trees on north aspects. The number of seed cones was most signigicantly correlated with tree height, and the number of pollen cones was significantly correlated with the number of seed cones. This study, thus, provided quantitative information to substantiate the recommendation that seedling seed orchards of black spruce be located on southerly sloping sites. On the basis of a literature review, Simpson (1981) also made recommendations for management techniques for seed orchards in New Brunswick.

## GENOTYPE X NITROGEN INTERACTIONS IN BLACK SPRUCE SEEDLINGS

A third graduate student, T.J. Mullin (of the Nova Scotia Department of Lands and Forests), is undertaking a greenhouse study of the geno-

type x nitrogen interactions during the first 25 weeks of growth of seedlings of 40 full-sib families of black spruce. The seeds were sown in January 1981. The objective is to investigate variation in the inherited capacity of black spruce seedlings to take up and use nitrogen.

## FUTURE OUTLOOK

Teaching and research are the traditional roles of the university, and as a result of the recent advent of undergraduate teaching in forest genetics, much remains to be done to strengthen this part of the program. Teaching must be interesting to the student, stimulate creativity, and be broadly based to illustrate the complex interrelationships in biological systems. At UNB, we have a chance to reach this goal through interdisciplinary work among faculty and through participation of research associates who have developed many experiments that illustrate important principles.

Research, too, will be cooperative to a large extent. The New Brunswick Tree Improvement Council and Nova Scotia Tree Improvement Working Group will offer opportunities for a variety of studies while providing training opportunities for students at the same time. During the next few years an increasing number of provenance experiments, progeny tests, and other trials will require measurement, analysis, and interpretation. These experiments are primarily concerned with Picea mariana, P. glauca, Pinus banksiana, Pinus resinosa Ait, Pinus strobus L., and Larix laricina, with some variation in the order of importance from one province to the next. Broad-leaved species (for example, those in the genus Betula) are only of local importance but will receive attention. More consultation with the individual companies and cooperative agencies will lead to definite plans in the near future.

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# SITE SELECTION FOR BLACK SPRUCE (PICEA MARIANA (MILL.) B.S.P.) SEEDLING SEED ORCHARDS AND MANAGEMENT TECHNIQUES FOR SEED ORCHARDS IN NEW BRUNSWICK

J.D. Simpson

*Fredericton, New Brunswick*
*E3B 5B8*

Key Words: black spruce, female strobili, male strobili, slope, aspect, seed orchard site selection, seed orchard management.

The following is an abstract of a report submitted for the M.F. degree at the University of New Brunswick, April, 1981.

Seed orchards are important for the production of quality seed for reforestation. To ensure maximum seed yield, orchards must be located on sites conducive to seed production and must be intensively managed. The objective of this study was to make recommendations on site selection for seedling seed orchards of black spruce and to review, on the basis of the available literature, seed orchard management techniques applicable in New Brunswick.

Ten plantations of black spruce of four ages were selected and a total of 300 trees were examined to elucidate the influence of site, tree age, and height on strobilus production on young trees. Trees growing on south-sloping sites produced two and one-half times more female and five times more male strobili than trees growing on north-sloping sites. Strobilus production on trees growing on south-sloping sites was also greater than that on trees growing on level sites. Number of female strobili was most significantly correlated with tree height. Number of male strobili was significantly correlated with number of female strobili. It is recommended that seed orchards be established on southeast through southwest-sloping sites or level sites with sandy loam or loamy sand soil.

The literature review of seed orchard management techniques revealed that the two types of seed orchards (seedling and clonal) should be treated differently. Generally, however, sites should be thoroughly prepared before orchard establishment, competing vegetation must be controlled at all times, and fertilizer may be applied to maintain and/or enhance tree growth and development and increase strobilus production. Irrigation may also be beneficial to tree growth and strobilus production. Seed orchards must be constantly monitored for and protected against insects, diseases, mammals, birds, and fires. Cone collection crews must be properly trained so as to minimize damage to the trees.

# THE TREE IMPROVEMENT WORKING GROUP IN NOVA SCOTIA -- A FIRST REPORT

T.J. Mullin

*Tree Breeding Centre*
*Department of Lands and Forests*
*Debert, Nova Scotia*
*B0M 1G0*

Key Words: government-industry cooperation, selection, seed orchards, grafting, genotype-nitrogen interaction.

This is the first formal report to the C.T.I.A. by a representative of the Nova Scotia Tree Improvement Working Group (TIWG). The time period covered is somewhat longer than usual, as an attempt has been made to provide an historical account of the development of tree improvement in Nova Scotia, and the formation of the TIWG program. Progress in plus-tree selection and seed orchard establishment is described.

## HISTORICAL

### The Early Days

The early work in tree improvement in Nova Scotia, and indeed all of the Maritime Provinces, was done primarily by the Canadian Forestry Service. Of particular note is the work of Dr. H.G. MacGillivray (retired) and Dr. D.P. Fowler, both of the Maritimes Forest Research Centre who established field tests of several species and provenances over much of the Maritimes. They were also responsible for the first delineation of seed zones and rules for seed transfer in the Maritimes (Fowler and MacGillivray 1967).

Interest in tree improvement within the province itself increased markedly in the early '70s as reforestation efforts were expanded to meet fibre requirements. Initial efforts focused on identification of high quality seed sources. Contracts were arranged to locate "superior" stands which could be reserved for seed collections (Sidhu 1972, Bailey 1973).

By the mid-70s, reforestation efforts had gained a higher priority, and both government and industry became interested in plus-tree selection and seed orchard establishment. A report on the potential of tree breeding in Nova Scotia determined that an applied tree improvement program was economically attractive, and could greatly enhance the productivity of planted stands (Mullin 1976). However, it was pointed out that a breeding program would not likely be productive unless it was carried out as a cooperative project among several agencies.

### The TIWG Is Formed

The idea of a cooperative tree improvement effort was not new, and appealed to the larger agencies who came together in April of 1977 to form the Tree Improvement Working Group. Membership in the TIWG is as follows:

Bowater Mersey Paper Company Limited
Nova Scotia Forest Industries
Scott Paper International, Inc.
Nova Scotia Department of Lands and Forests (NSLF)
Canadian Forestry Service (Maritimes Forest Research Centre)

With the exception of the CFS, all members participate in the operational aspects of the program: selection, seed orchard management, testing, etc. Planning and coordination of the overall program is carried out by the Tree Breeding Section of the Department of Lands and Forests, working closely with technical advisors and research scientists at the Maritimes Forest Research Centre.

During the first year of the TIWG program, members participated on a completely informal basis, becoming familiar with breeding methods and developing ideas for a cooperative improvement strategy. Late in 1977, the Management Committee of the TIWG assembled a five-year work plan which spelled out performance targets for each agency (TIWG 1977). The allocation of workload (and benefits) was proportioned according to the nursery production targets of each agency. High-level officials then exchanged letters of commitment to the five-year plan.

## PROGRESS TO DATE

### Selection

Since the TIWG was formed, over 650 plus-trees have been selected for inclusion in the program. Emphasis was placed on selection of white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), and red spruce (*Picea rubens* Sarg.), as these make up the majority of nursery stock planted in the province. However, plus-trees have also been selected in white pine (*Pinus strobus* L.), jack pine (*Pinus banksiana* Lamb.), and Norway spruce (*Picea abies* (L.) Karst.).

Selection is performed using a comparison tree method based on the North Carolina State University system, with slightly different criteria used for each species. All selected candidates are inspected by Tree Breeding Section staff before being approved for breeding work. Black spruce and jack pine plus-trees are felled and seed collected for development of seedling seed orchards. Scions from red, white, and Norway spruce, and white pine are grafted for establishment in clonal seed orchards.

### Seed Orchards

A small (1.6 hectares) red spruce orchard was established in 1977 by the Department of Lands and Forests in Lawrencetown, Annapolis Co., as a

result of early selection and grafting efforts. Since the formation of the TIWG, an additional 4.7 hectares of grafted orchard (3750 ramets) have been established at three locations. Scions are collected from plus-trees by climbing crews employed by the industrial members. Grafting is done by Tree Breeding Section staff, who tend the seedlings until ready for shipment to orchard sites. Over 6000 ramets are currently being held in transplant beds at the Tree Breeding Centre in Debert. A clone bank containing over 700 ramets has also been established to produce additional scion material and to facilitate controlled pollination work.

Grafted orchards are planted at 5 x 2.5 m spacing, anticipating removal of 50% of the trees through mortality and roguing as a result of progeny testing. The orchard design is based on the permutated neighbourhood concept, using a computer program adapted from Bell and Fletcher (1978). Output from the program was modified somewhat to simplify packing procedures in the nursery and identification of planting locations in the field.

A 3.6 hectare seedling seed orchard was established in 1978 using white spruce seed collections from the Ottawa Valley. Preliminary test results indicate that these sources may have significant potential in this region (Fowler and Coles 1977). Seed collections have been made for two black spruce seedling seed orchards and associated family tests to be established in the spring of 1982. One of these orchards will produce seed intended for use on the Highlands of Cape Breton. The second orchard will serve the remainder of the province, and will be established from selected trees in Nova Scotia and southern New Brunswick.

Virtually every member of the TIWG has experienced difficulties in locating seed orchard sites. Large areas with suitable soils, topography, access and climate are extremely rare on freehold and leased lands. This has led some members to negotiate purchases of land in the Annapolis Valley of Nova Scotia which is considered to have climate and soils highly suited to seed production (Coles 1980).

## Test Plantations

Since 1977, members of the TIWG have outplanted over 20 hectares of test plantations. These include tests of black spruce stands in Nova Scotia and New Brunswick, white spruce from Nova Scotia and the Ottawa Valley, and red spruce from local sources. Tests of hybrid spruce and larch (*Larix* Mill.) materials have also been established in cooperation with the Maritimes Forest Research Centre.

## Tree Breeding Centre

Until recently, grafting and production of test seedling stock was carried out at Provincial forest nurseries, and at the Acadia Forest Experiment Station near Fredericton, New Brunswick. Early in 1981, facilities at the Tree Breeding Centre at Debert in central Nova Scotia were put into operation (Figures 1 and 2). The Centre is operated by Tree Breeding Section personnel and was built with assistance from The Department of Regional Economic Expansion.

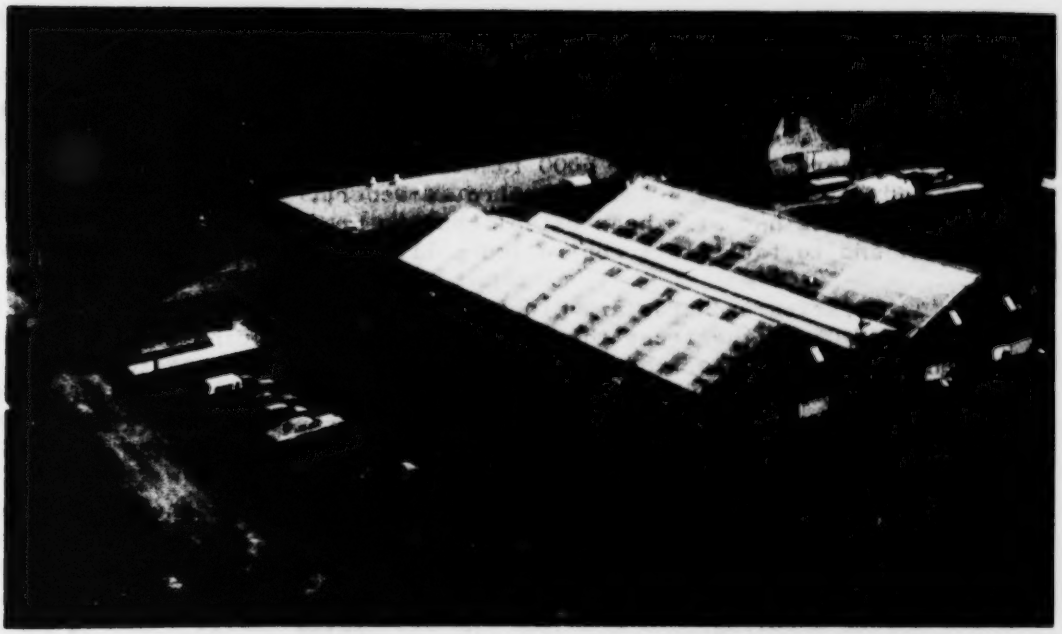

Figure 1. The Tree Breeding Centre, Debert, Nova Scotia began operation early in 1981. Built by the Department of Lands and Forests with assistance from DREE, the Centre provides nursery, office, and lab facilities to serve the Tree Improvement Working Group program.

Figure 2. Over 6,000 spruce grafts are tended in one of the Centre's greenhouse zones. The zone is equipped with a double poly roof, rolling bench system, under-the-bench heating, pad cooling, combination irrigation/fertilization/photoperiod control boom, high-pressure sodium lighting, and shade/thermal blanket system.

The facility consists of greenhouse, laboratory and office space devoted to providing special services to the TIWG program, and is located adjacent to a 210 ha area reserved for seed orchard development by NSLF. The 930 $m^2$ greenhouse is divided into four equal-sized zones, each under independent climate control. This configuration has proven to be extremely useful, as ideal climate conditions can be maintained for grafted or rooted seedlings, while a neighbouring zone is being used to germinate a family test.

## MISCELLANEOUS

From September 1980 to May 1981, I was on educational leave from NSLF to fulfill the residence requirements for an M.Sc.F. degree at the University of New Brunswick, specializing in forest genetics. Dr. E.K. Morgenstern and Dr. D.P. Fowler are co-supervising my thesis research, investigating genotype-nitrogen interactions in black spruce seedlings. A disconnected diallel mating design was used to produce 40 full-sib families which were grown under three levels of nitrogen in a replicated greenhouse experiment. Work in this area will continue beyond the scope of the thesis as part of the TIWG program.

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# TRIALS OF EXOTIC SPECIES AND GENETIC IMPROVEMENT OF LARCH IN NEWFOUNDLAND

J. Peter Hall

*Newfoundland Forest Research Centre*
*Canadian Forestry Service*
*St. John's, Newfoundland*
*A1C 5X8*

Key Words: exotics, hybridization, microsporogenesis, seed yield.

Trials of exotic conifers have now been underway in Newfoundland for fifteen years and preliminary assessments are now being made of their suitability. In general, the pines and spruces tested have not proven superior in growth rates to native species but Larix kaempferi and L. eurolepis have.

The effects of low temperature on pollen development in Larix is being studied to determine if pollen sterility results in low seed yields. Early data indicate that low temperatures do not cause pollen sterility in native Larix but may in exotic Larix.

A series of controlled pollinations has been done on Picea mariana and P. glauca to compare the effects of self-pollination, cross-pollination and open-pollination.

## I. TRIALS OF EXOTIC SPECIES

### 1. Plantation of Exotic Pinus Species

This plantation was established on a burned cutover in 1966 with two year old stock. Four species, P. sylvestris, P. banksiana, P. contorta and P. resinosa had survival of 75% or greater. Three species, P. albicaulis, P. cembra and P. nigra v. corsicana were rated as failures. Average total height was greatest for P. banksiana and least for P. resinosa (Table 1). Differences between replications were also statistically significant, a reflection of the varied site conditions within the plantation.

Compared to black spruce regeneration in the area, however, the heights attained by the pines are not impressive. At 15 years black spruce natural regeneration can be expected to grow to a height of 3.5 to 4.0 metres so there is little advantage in terms of productivity gained by use of the exotic species.

Table 1. Average total height of 15-year old Pinus.

| Species | Origin | Avg. total ht. (m) |
|---|---|---|
| Pinus banksiana | Newcastle, New Brunswick | 3.58* |
| P. sylvestris | Kuorevesi, Finland | 2.70 a |
| P. sylvestris | Morayshire, U.K. | 2.50 ab |
| P. contorta | Long Beach, Washington, U.S.A. | 2.39 ab |
| P. resinosa | Petawawa NFI, Ontario | 1.84 b |

*Means followed by the same letter are not statistically different from each other at p level 0.95.

2. Plantation of Native and Exotic Larix

Remeasurements were made in 1980 on a plantation of exotic Larix when the trees were eight years old from seed. Survival was poor in some species (Table 2) because many trees had poor root development

Table 2. Survival and average total height of Larix plantation trial.

| Species | Origin | Percentage survival | Avg. total ht. (m) |
|---|---|---|---|
| Larix laricina | Petawawa NFI, Ontario | 97.8 a | 1.21 a |
| L. eurolepis | Mabie Seed Orchard, Scotland | 83.3 ab | 1.49 b |
| L. eurolepis | Newton Seed Orchard, Scotland | 67.8 b | 1.56 b |
| L. sibirica | Krasnojarsk, USSR | 57.8 bc | 1.32 a |
| L. kaempferi | High Meadow Forest, England | 50.0 c | .62 c |
| L. sibirica | Krasnojarsk, USSR | 43.3 c | .92 d |

in the nursery and because both L. kaempferi and L. sibirica had flushed before planting. (It is essential in Newfoundland to grow late flushing varieties of larch and to plant them as early in the spring as possible.) None of the exotics have survived as well as the native L. laricina. Once established, however, both L. kaempferi and L. eurolepis grew faster than the L. laricina. Both seedlots of L. eurolepis were significantly taller than L. laricina.

3. Comparison of 15-Year-Old Native and Exotic Species

Comparisons of planted native and exotic species on both upland and barren sites (Tables 3, 4) have shown that Larix generally outgrows native black spruce and other exotic pines and spruces and that on some sites L. kaempferi outgrows all other larches.

The results indicate an excellent potential for the introduction of Larix as reforestation species in Newfoundland.

Table 3. Average total height of planted Picea mariana and Larix spp. on three productive upland sites in western, central and eastern Newfoundland.

| Species | Origin | Avg. total ht. (m) after 15 yrs. | | |
|---|---|---|---|---|
| | | Western | Central | Eastern |
| Picea mariana | Northumberland Co., N.B. | 3.13 | 1.48[1] | 1.68 |
| Larix laricina | Guysborough Co., N.S. | 4.58 | 4.68 | 2.90 |
| L. decidua | Central Europe | 4.72 | 2.16 | 1.88 |
| L. decidua | Region VI, Germany | 4.52 | 1.86 | 2.27 |
| L. kaempferi | Region VII, Germany | 4.97 | 3.03 | 2.52 |
| L. kaempferi | Region VII, Germany | 4.79 | 3.64 | 3.15 |
| L. kaempferi | Mt. Yatsugatake, Nagano, Japan | 5.31 | 2.45 | 2.87 |

[1]This seedlot was severely suppressed by nearby regeneration. Natural regeneration in the area averages about 4 m at age 15.

Table 4. Average total height (m) of Larix and other conifers on ploughed peat bog and on a ploughed heath.

| Species | Origin | Ploughed peat bog | Ploughed heath |
|---|---|---|---|
| Larix laricina | Guysborough Co., N.S. | - | 4.12 |
| L. kaempferi | Region VII, Germany | 2.35 | - |
| Picea mariana | Badger, central Newfoundland | .53 | 1.20 |
| P. glauca | Guysborough Co., N.S. | - | 1.21 |
| P. abies | Vilppula, Finland | .24 | - |
| P. sitchensis | Terrace, B.C. | .24 | - |
| Pinus banksiana | Northumberland Co., N.B. | - | 3.28 |
| P. sylvestris | Kuorevesi, Finland | 1.31 | - |
| P. sylvestris | Morayshire, U.K. | - | 2.73 |

## II. GENETIC IMPROVEMENT OF NATIVE CONIFERS

### 1. Genetic Improvement of Larch, L. laricina

#### (i) Pollen development

The relationship between pollen development and climate is being studied in L. laricina, L. kaempferi, L. decidua and L. eurolepis. Studies of pollen development have been completed in L. laricina. Results showed that pollen mother cells began development from Interphase in early to mid-October passing through Leptotene, Zygotene and Pachytene by 10 November. They remained in Diplotene until mid-March to early April when meiosis was completed over a two to four week period. Microspores were produced by early May. The general pattern of meiotic divisions, their sequence, duration and variability within and between trees was similar to that reported earlier for L. decidua, L. kaempferi, L. sibirica and L. eurolepis.

Deviation from the normal pattern occurred infrequently. In six trees the "resting Diplotene" of the winter was interrupted on one occasion and some male strobili had a "delayed meiosis" which occurred several days after meiosis in all other sampled strobili. Abnormal chromosome separations were observed on a few occasions, these consisted mostly of lagging chromosomes, a common abnormality in Larix.

There appeared to be no causal relationship between temperature and the onset of the various stages of meiosis. The number of abnormalities observed indicated that the low seed sets observed in L. laricina could not be attributed to sterile pollen arising from temperature-induced damage.

Examination of the pollen mother cells of the exotic larches indicated that meiotic development occurs two to four weeks earlier than L. laricina. A higher proportion of damaged cells was observed in the exotics but as yet, data are too few to show whether seed production is likely to be affected.

#### (ii) Inter-specific and intra-specific hybridization

A series of controlled pollinations was done on L. laricina, L. kaempferi, L. eurolepis and L. decidua in 1980. Inter- and intra-specific crosses were made and year-old stored pollen was tested. Seed has been extracted and seedlings will be grown as soon as local facilities are available. Self-pollinations were also done on each mother tree.

### 2. Genetic Improvement of Black Spruce

A series of single-tree pollinations was done to assess yields of seed after open-pollination, cross-pollination and self-pollination. A total of six mother trees 15 to 18 years old of natural origin were used. Seed has been extracted and will be sown in 1981.

A study on plus tree selection was continued. The object was to determine if it was practical to select plus trees for high density without sacrificing growth rate. Most of the fieldwork has been completed and preliminary results indicate that the two variables are not related meaning that selection can be based on one but not both criteria. There also appears to be an equally wide range of variability in growth rate and density.

3. Genetic Improvement of White Spruce

Trees in a 20-year old provenance trial were selected for a series of controlled pollinations. A series of intra- and inter-provenance crosses was done using both fresh pollen and pollen stored for one year. Some cones were lost to squirrels, only recently introduced into Newfoundland. Seed has been extracted and will form part of a seedling seed orchard to be established by the provincial government.

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ATTENDANCE, AUGUST 1981

# PROCEEDINGS, PART 2

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## SEED ORCHARDS AND STRATEGIES FOR TREE IMPROVEMENT

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# ATTENDANCE

Eighteenth Meeting, Canadian Tree Improvement Association
Duncan, British Columbia, August, 1981

Mr. R.F. Ackerman
Canadian Forestry Service
Petawawa National Forestry Institute
Chalk River, Ontario K0J 1J0

Mr. B.P. Adams
Canadian Forest Products Limited
9621 - 85th Ave.
Grande Praire, Alberta

Mr. G.M. Albricht
Ministry of Forests
R.R. 1
Tappen, British Columbia

Mr. H.G. Anderson
Alberta Energy & Natural Resources
Forest Technology School
1176 Switzer Drive
Hinton, Alberta T0E 1B0

Ms. D. Andrew
Pacific Forest Products
8067 East Saanich Road
Saanich, British Columbia

Mr. S.M. Baker
Ministry of Forests - Research
4300 North Road
Victoria, British Columbia

Mr. D.J. Barker
T.M. Thomson & Associates
1006 Government Street
Victoria, British Columbia

Dr. J.E. Barker
Western Forest Products Ltd.
1020 Beckwith Ave.
Victoria, British Columbia

Mr. F.D. Barnard
Western Tree Seeds Ltd.
Box 144
Blind Bay, British Columbia

Mr. V.C. Bartram
Ministry of Forests - Silviculture
1450 Government Street
Victoria, British Columbia

Mr. J.M. Bégin
CIP Incorporated
Sunlife Building
Montreal, Québec

Mr. H.E.B. Bell
ITT Rayonier
P.O. Box 539
Hoquiam, Washington 98550

Mr. R.D.B. Bettle
NB Dept. of Natural Resources
Provincial Forest Nursery
R.R. 6
Fredericton, New Brunswick
E3B 4X7

Mr. C.N. Birkett
Ministry of Forests
Box 1343
Port Hardy, British Columbia
V0N 2P0

Mr. P. Birzens
Ministry of Forests
3401 Reservoir Road
Vernon, British Columbia

Mr. R. Bowden-Green
Ministry of Forests - Seed Centre
Box 816
Duncan, British Columbia

Dr. R.C. Bower
MacMillan Bloedel Limited
65 Front Street
Nanaimo, British Columbia
V9R 5H9

Mr. T.J. Boyle
Canadian Forestry Service
Petawawa National Forestry Institute
Chalk River, Ontario K0J 1J0

Mr. L.G. Brace
Canadian Forestry Service
Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta

Mr. D.G. Brand
Weldwood of Canada
Box 2179
Vancouver, British Columbia

Dr. G.P. Buchert
Ministry of Natural Resources
Ontario Tree Improvement and Biomass Institute
Maple, Ontario L0J 1E0

Mr. W.G. Camenzind
Ministry of Forests
Box 3369
Smithers, British Columbia

Dr. L.W. Carlson
Canadian Forestry Service
Place Vincent Massey
351 St. Joseph Blvd.
Hull, Québec

Mr. D.W. Carson
Ministry of Forests - Research
Cowichan Lake Research Centre
Box 335
Mesachie Lake, British Columbia
V0R 2N0

Mr. T.A. Carter
Ministry of Forests - Silviculture
R.R. 7 15 Mile Road
Prince George, British Columbia

Mr. W.M. Cheliak
Canadian Forestry Service - PNFI
c/o University of Alberta
Dept. of Forest Science
Edmonton, Alberta T6G 2G6

Mr. G. Clarke
Ministry of Forests
Vernon, British Columbia

Mr. T. Clement
Canadian Forest Products
R.R. 2
Gibsons, British Columbia

Mr. J.F. Coles
Canadian Forestry Service
Maritimes Forest Research Centre
P.O. Box 4000
Fredericton, New Brunswick

Mr. R.H. Collins
Western Forest Products Ltd.
1020 Beckwith Ave.
Victoria, British Columbia

Mr. J.M. Conway
Consolidate Bathurst Inc.
32 - 3 Ave.
Grand-Mère, Québec

Dr. A. Corriveau
Centre de recherche forestières des Laurentides
C.P. 3800, Ste-Foy
Québec 10, P.Q., G1V 4C7

Mr. J.F. Couturié
Scott Paper Co.
P.O. Box 925
Everett, Washington 98203

Mr. K.W. Cox
Ministry of Forests
Skimikin Seed Orchard
General Delivery
Tappen, British Columbia
V0E 2Z0

Mr. T. Crowder
Ministry of Forests
Box 25
Campbell River, British Columbia

Mr. M. Crown
Ministry of Forests
Box 816
Duncan, British Columbia
V9L 3Y2

Mr. G. Caron
University of New Brunswick
Dept. of Forestry Resources
Bag Serv. 44555
Fredericton, New Brunswick

Mr. B.J. Currel
Ministry of Forests
Box 816
Duncan, British Columbia
V9L 3Y2

Dr. B.P. Dancik
University of Alberta
Dept. of Forest Science
Edmonton, Alberta T6G 2G6

Mr. B. Devitt
Pacific Forest Products
P.O. Box 10
Victoria, British Columbia

Dr. N.K. Dhir
Reforestation & Reclamation
Branch
Alberta Forest Service
9915 - 108 St.
Edmonton, Alberta

Mr. K.A. Donkersley
Pacific Forest Products
P.O. Box 10
Victoria, British Columbia

Mr. D. Dotter
Weyerhaeuser Company
16014 Pletzer Road, S.E.
Turner, Oregon

Mr. G.B. Dunsworth
MacMillan Bloedel Ltd.
65 Front Street
Nanaimo, British Columbia
V9R 5H9

Mr. I.J. Dymock
Canadian Forestry Service
Northern Forest Research Centre
5320 - 122nd Street
Edmonton, Alberta

Dr. D.G. Edwards
Canadian Forestry Service
Pacific Forest Research Centre
506 W. Burnside Road
Victoria, British Columbia

Dr. Y. El-Kassaby
University of British Columbia
Faculty of Forestry
Vancouver, British Columbia
V6G 1J3

Mr. C.P. Endall
Ministry of Forests
Silviculture
1011 - 4th Ave.
Prince George, British Columbia
V2L 2T4

Mr. K.C. Eng
Ontario Ministry of Natural
Resources
10670 Yonge St.,
Richmond Hill, Ontario L4C 3C9

Ms. K. Falusi
University of Toronto
School of Forestry
Toronto, Ontario

Ms. A.M. Fashler
Pacific Forest Products
8067 E. Saanich Road
Saanich, British Columbia

Mr. R. Faulkner
U.K. Forestry Commission
Northern Research Station
Roslin, Lothian
Scotland

Mr. E.J.E. Feeley
University of British Columbia
Faculty of Forestry
904 - 2020 Haro St.
Vancouver, British Columbia
V6G 1J3

Ms. P. Flinn
Alberta Forest Service
Box 750
Smoky Lake, Alberta

Dr. W.H. Fogal
Canadian Forestry Service
Petawawa National Forestry Institute
Chalk River, Ontario K0J 1J0

Mr. P.G. Fowler
Ministry of Forests
518 Lake Street
Nelson, British Columbia

Mr. L.M. Glen
Reid Collins Nurseries
Box 430
Aldergrove, British Columbia

Mr. H.J. Goodman
Weldwood of Canada
Box 2000
Quesnel, British Columbia

Dr. A. Gordon
Ontario Ministry of Natural Resources
Central Forest Research Unit
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 4H1

Mr. R.W. Gray
Ministry of Forests
540 Borland Street
Williams Lake, British Columbia

Mr. V.F. Haavisto
Canadian Forestry Service
Great Lakes Forest Research Centre
Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Mr. B.D. Haddon
Canadian Forestry Service
Petawawa National Forestry Institute
Chalk River, Ontario K0J 1J0

Dr. J.P. Hall
Canadian Forestry Service
Newfoundland Forest Research Centre
St. John's, Newfoundland

Mr. J.C. Heaman
Ministry of Forests - Research
1450 Government Street
Victoria, British Columbia
V8W 3E7

Dr. C. Heimburger
2060 McNeill Ave.
Victoria, British Columbia
V8S 2X8

Mr. W.A. Henderson
Box 220 Gold River
Tahsis Co. Ltd.
British Columbia

Mr. C.A. Hewson
Ministry of Forests - Red Rock Nursery
R.R. 7 15 Mile Road
Prince George, British Columbia
V2N 2J5

Mr. B.J. Higgs
Valley Forest Products
P.O. Box 1000
Nackawic, New Brunswick

Mr. D. Hodgin
Weyerhaeuser Company
7935 Hwy. 12 S.W.
Rochester, Washington 98579

Ms. C. Holbek
Ministry of Forests
No. 210 - 355 Burrard St.
Vancouver, British Columbia

Mr. J.V. Hood
Ontario Forest Research Centre
Maple, Ontario L0J 1E0

Mr. K. Illingworth
Ministry of Forests - Research
1450 Government Street
Victoria, British Columbia
V8W 3E7

Mr. B.C. Jaquish
Ministry of Forests
3806 - 38 St.
Vernon, British Columbia

Mr. H.P. Jensen
R.R. 7
Duncan, British Columbia
V9L 4W4

Mr. S. John
Canadian Forest Products
R.R. 1, Chapman Road
Sechelt, British Columbia

Mr. C.M. Johnson
Ministry of Forests -
Silviculture
1450 Government Street
Victoria, British Columbia
V8W 3E7

Mr. I. Karlsson
Ministry of Forests
359 Dogwood Place
Duncan, British Columbia

Mr. G.K. Kiss
Ministry of Forests
3401 Reservoir Road
Vernon, British Columbia

Dr. J. Klein
Canadian Forestry Service
Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta

Mr. J. Konishi
Ministry of Forests -
Silviculture
1450 Government St.
Victoria, British Columbia
V8W 3E7

M. Y. Lamontagne
Dept. of Energy and Resources
Service de la Restauration
200 B. CH
Ste.-Foy, Québec G1R 4X7

Mr. J.L. Ladner
International Paper Co.
P.O. Box 308
Veneta, Oregon 97487

Dr. Carole L. Leadem
Ministry of Forests - Research
4300 North Road
Victoria, British Columbia

M. H.N. LeBlanc
Canadian Forestry Service
351 St. Joseph Blvd.
Place Vincent Massey
Hull, Québec

Mr. R.M. Lee
Champion International
P.O. Box 10228
Eugiene, Oregon 97440

Dr. D.T. Lester
Crown Zellerbach
Forestry Research Station
P.O. Box 368
Wilsonville, Oregon 97070

Mr. S.W. Lorimer
Crown Zellerbach
No. 21B - 2220 Bowen Road
Nanaimo, British Columbia

Mr. J.E. Lort
Ministry of Forests - Research
4300 North Road
Victoria, British Columbia

Mr. M.D. Maguire
Ministry of Forests
R.R. 7 15 Mile Road
Prince George, British Columbia

Ms. J. Martin
Crown Zellerbach
Box 368
Wilsonville, Oregon 97070

Dr. C.J. Masters
Weyerhaeuser Company
505 N. Pearl St.
Centralia, Washington

Dr. J. Maze
University of B.C. - Dept of Botany
Vancouver, British Columbia
V6T 2B1

Dr. M. Meagher
Ministry of Forests - Research
1450 Government Street
Victoria, British Columbia
V8W 3E7

Mr. R.D. Meier
ITT Rayonier
P.O. Box 539
Hoquiam, Washington 98550

Mr. G.E. Miller
Canadian Forestry Service
Pacific Forest Research Centre
Victoria, British Columbia

Dr. E.K. Morgenstern
Department of Forest Resources
University of New Brunswick
Bag No. 44555
Fredericton, New Brunswick
E3B 6C2

Mr. W.G. Morrow
Ministry of Forests
R.R. 2 Puckle Road
Saanichton, British Columbia
V0S 1M0

Mr. T.J. Mullin
N.S. Dept. of Lands and Forests
Tree Breeding Centre
Debert, Nova Scotia B0M 1G0

Mr. K. Munroe
Weyerhaeuser
210 Nelson Road, W.
Sequim, Washington 98382

Dr. G. Murray
Canadian Forestry Service
Petawawa National Forestry Institute
Chalk River, Ontario K0J 1J0

Mr. W. McMullan
Western Forest Products
Jordan River, British Columbia
V0S 1L0

Dr. H. Nienstaedt
U.S. Forest Service
North Central Forest Exp. Station
Forestry Sciences Lab.
Box 898
Rhinelander, WI 54501

Mr. C. O'Reilly
Lakehead University
School of Forestry
Thunder Bay, Ontario

Dr. J.N. Owens
University of Victoria
Biology Department
Victoria, British Columbia

Dr. Y.S. Park
Canadian Forestry Service
Maritimes Forest Research Centre
P.O. Box 4000
Fredericton, New Brunswick
E3B 5P7

Dr. W.H. Parker
Lakehead University
School of Forestry
Thunder Bay, Ontario P7B 5E1

Dr. D.F. Pollard
19th Floor Place Vincent
Massey
Hull, Québec
K1A 1G5

Mr. F.T. Portlock
Canadian Forestry Service
Pacific Forest Research Centre
506 W. Burnside
Victoria, British Columbia

Dr. G.R. Powell
University of New Brunswick
Faculty of Forestry
BAG No. 44555
Fredericton, New Brunswick
E3B 6C2

Ms. R.M. Rauter
Ontario Ministry of Natural
Resources
Whitney Block, Queens Park
Toronto, Ontario

Mr. J. Reno
Weyerhaeuser Company
Centralia, Washington

Mr. J. Richardson
Canadian Forestry Service
Newfoundland Forest Research
Centre
P.O. Box 6028
St. John's, Newfoundland

Ms. D.M. Roddy
Prince Albert Pulpwood
Box 1720
Prince Albert, Saskatchewan
S6V T5E

Dr. S.D. Ross
Ministry of Forests - Research
1450 Government St.
Victoria, British Columbia
V8W 3E7

Mr. O. Rosvall
Institute for Forest Improvement
Ringvagen 43 - 91036 Savar
Sweden

Mr. D.S. Rudolph
Ministry of Forests
Box 816
Duncan, British Columbia
V9L 3Y2

Dr. T.D. Rudolph
U.S. Forest Service
North Central Forest Experiment
Station
Forestry Sciences Lab., Box 898
Rhinelander, Wisconsin 54501

Ms. H.A. Rutherglen
Ministry of Forests
Box 816
Duncan, British Columbia
V9L 3Y2

Dr. T.S. Sahota
Canadian Forestry Service
Pacific Forest Research Centre
Victoria, British Columbia

Mr. I.H. Schiedel
20206 Dewdney Trunk
Maple Ridge, British Columbia
V2X 3E2

Ms. J.M. Schilf
Alberta Forest Service
Box 750
Smoky Lake, Alberta

Dr. H O. Schooley
Canadian Forestry Service
Newfoundland Forest Research
Centre
58 Edmonton Place
St. John's, Newfoundland

Dr. H. Singh
University of Victoria
Biology Dept.
Victoria, British Columbia

University of Delhi
Botany Department
Delhi - 110007, India

Mr. S. Segaran
Department of Natural Resources
Forestry Branch
300 - 530 Kenaston Blvd.
Winnipeg, Manitoba L3N 1Z4

Mr. A. Shortreid
B.C. Forest Products
Box 130
Crofton, British Columbia
V0R 1R0

Ms. F. Simmonds
Ontario Ministry of Natural Resources
199 Larch St.
Sudbury, Ontario

Mr. R.F. Smith
Canadian Forestry Service
Maritimes Forest Research Centre
P.O. Box 4000
Fredericton, New Brunswick
E3B 5P7

Ms. E.B. Sommerfield
Ministry of Forests
Box 816
Duncan, British Columbia
V9L 3Y2

Dr. R.D. Stevens
Bureau of Land Management
777 NW Garden Valley Blvd.
Roseburg, Oregon 97470

Mr. E.D. Stinson
New Brunswick Dept. of Natural Resources
Provincial Forestry Nursery
R.R. 6
Fredericton, New Brunswick
E3B 4X7

M. A.S. Stipanicic
Min. des Terres et Forets
Service De La Recherche Forestiere
2700 Rue Einstein
St. Foy, Québec G1P 3W8

Mr. B. Stretch
Mt. Newton Seed Orchard
1450 Mt. Newton X Road
R.R. 2
Saanichton, British Columbia

Mr. D.W. Summers
Ministry of Forests - Silviculture
1450 Government St.
Victoria, British Columbia
V8W 3E7

Dr. J. Sutherland
Canadian Forestry Service
Pacific Forest Research Centre
Victoria, British Columbia

Dr. O. Sziklai
University of British Columbia
Faculty of Forestry
Vancouver, British Columbia

Dr. J.T. Talbert
N.C. State University
Raleigh, North Carolina 27511

Mr. D.W. Taylor
Canadian Forestry Service
Pacific Forest Research Centre
595 Ridgegrove Ave.
Victoria, British Columbia

Mr. J. Thompson
Dept. Tourism and Renewable Resources
Forestry Branch
Rm. 300 - 49 12th St. E.
Prince Albert, Saskatchewan
S6V 1B5

Mr. J. Toman
Consultant
Box 73
Little Fort, British Columbia

Dr. J.P. VanBuijtenen
Texas University
Forest Genetics Lab
College Station, Texas 77843

Mr. B. Wang
Canadian Forestry Service
Petawawa National Forestry Institute
Chalk River, Ontario K0J 1J0

Dr. J.E. Webber
Ministry of Forests
4300 North Road
Victoria, British Columbia

Mr. J.L. Weber
Simpson Timber Company
3rd and Franklin
Shelton, Washington

Mr. T.A. Westergreen
Georgia Pacific Corp.
4800 South Pass Road
Sumas, Washington 98295

Dr. T.W. White
International Paper Company
34937 Tennessee Road
Lebanon, Oregon 97355

Mr. F. Wiesinger
Wiesinger Systems Ltd.
1065 - 167 Lombard Ave.
Winnipeg, Manitoba

Mr. B.C. Wilson
Washington State Dept. of Natural Resources
Forest Land Management
Olympia, Washington 98504

Mr. D. Winston
Canadian Forestry Service
Place Vincent Massey
351 St. Joseph Blvd.
Hull, Québec

Mr. C.Y. Woon
Ministry of Forests - Research
1450 Government St.
Victoria, British Columbia
V8W 3E7

Mr. R.A. Wright
Weyerhaeuser Company
445 Kitchen Lane
Sequim, Washington 98382

Dr. F.C. Yeh
Ministry of Forests - Research
1450 Government Street
Victoria, British Columbia

Mr. D.T. Young
Procter and Gamble Cellulose
Postal Bag 1020
Grande Prairie, Alberta

Dr. C.C. Ying
Ministry of Forests - Research
1450 Government Street
Victoria, British Columbia

# Number/
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# 2

# SEED ORCHARDS AND STRATEGIES FOR TREE IMPROVEMENT

PROCEEDINGS OF THE EIGHTEENTH MEETING OF THE CANADIAN TREE IMPROVEMENT ASSOCIATION

PART 2

DUNCAN
BRITISH COLUMBIA
AUGUST 17-20, 1981

EDITORS
D.F.W. POLLARD
D.G. EDWARDS
C.W. YEATMAN

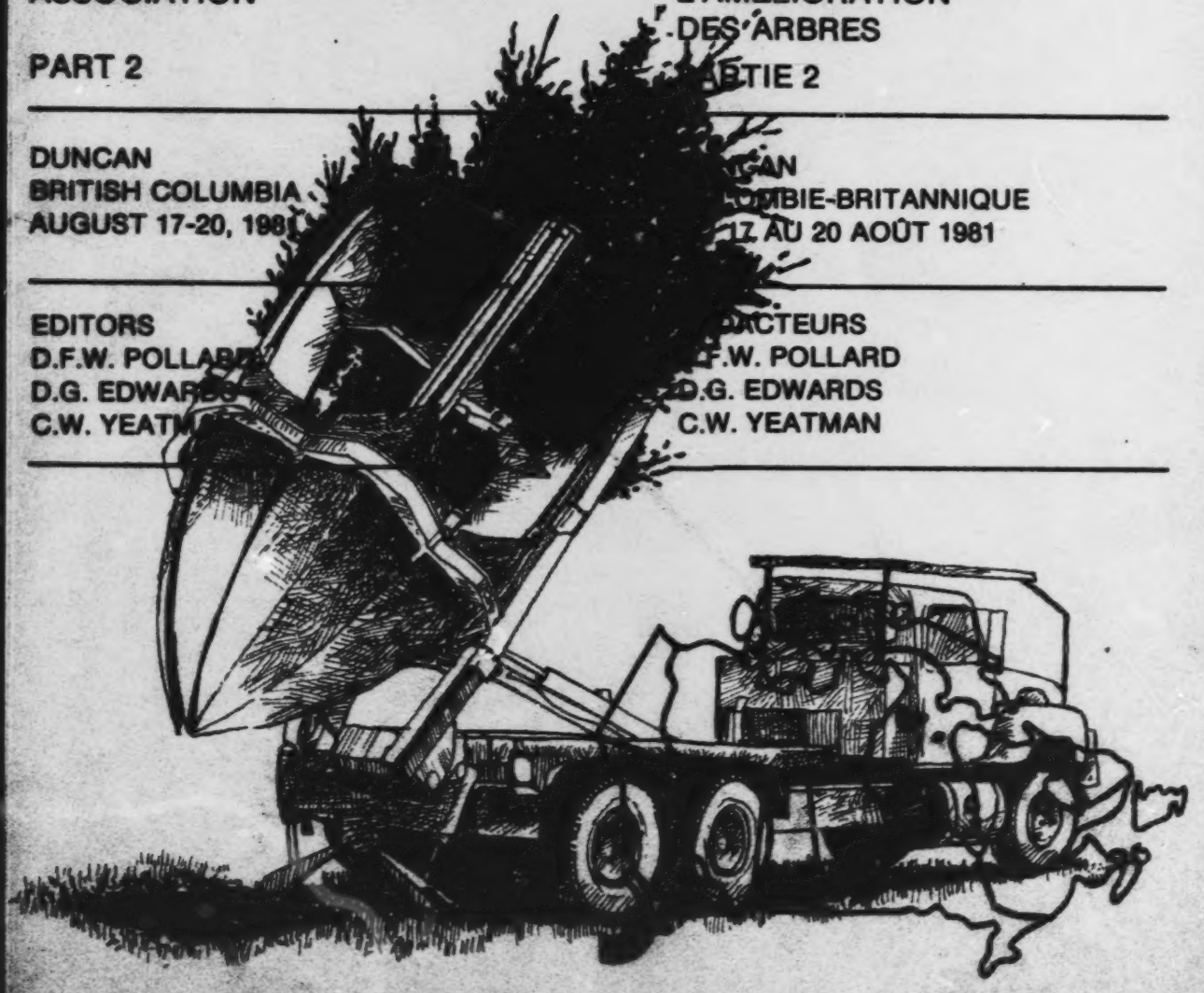
# COLLOQUE SUR LES VERGERS À GRAINES ET LES STRATÉGIES D'AMÉLIORATION DES ARBRES

COMPTE RENDUS DE LA DIX-HUITIÈME RÉUNION DE L'ASSOCIATION CANADIENNE POUR L'AMÉLIORATION DES ARBRES

PARTIE 2

DUNCAN
COLOMBIE-BRITANNIQUE
17 AU 20 AOÛT 1981

RÉDACTEURS
D.F.W. POLLARD
D.G. EDWARDS
C.W. YEATMAN



PROCEEDINGS

OF THE EIGHTEENTH MEETING

OF THE

CANADIAN TREE IMPROVEMENT

ASSOCIATION

PART 2:

SYMPOSIUM ON

# SEED ORCHARDS AND STRATEGIES FOR TREE IMPROVEMENT

DUNCAN, BRITISH COLUMBIA

AUGUST 17-20, 1981

EDITORS: D.F.W. POLLARD, D.G.W. EDWARDS AND C.W. YEATMAN

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**COMPTES RENDUS**

**DE LA DIX-HUITIÈME CONFÉRENCE**

**DE**

**L'ASSOCIATION CANADIENNE POUR**

**L'AMÉLIORATION DES ARBRES**

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**COLLOQUE SUR**

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**DU 17 AU 20 AOÛT 1981**

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Ottawa, 1982

PROCEEDINGS OF THE EIGHTEENTH MEETING OF

THE CANADIAN TREE IMPROVEMENT ASSOCIATION

**With the compliments of the Association**

*Enquiries may be addressed to the authors or to* Mr. M.J. Coles, Executive Secretary, C.T.I.A./A.C.A.A., N.B. Executive Forest Research Committee Inc. 500 Beaverbrook Court, Fredericton, N.B. E3B 5X4.

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---

**To:** *Dr. C.W. Yeatman, Editor, C.T.I.A./A.C.A.A.*
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*La dix-neuvième conference de l'Association aura lieu à Toronto, Ontario, du 22 au 26 Août 1983. Des orateurs seront invités à s'adresser au sujet de la propagation végétative et son impact sur l'amélioration génétique et sur nos forêts futures. Tous sont bienvenues. Des informations supplémentaires seront distribuées durant l'automne de 1982 à tous les membres et à tous ceux qui en feront la demande. Ces demandes de renseignements concernant la dix-neuvième réunion devrons être adressées à: Miss R.M. Rauter, Chairman, C.T.I.A./A.C.A.A., Forest Resources Branch, Ontario Ministry of Natural Resources, Parliament Buildings, Toronto, Ontario M7A 1W3.*

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**À:** *Dr. C.W. Yeatman, rédacteur, A.C.A.A./C.T.I.A.*
*Environnement Canada*
*Service canadien des forets*
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D.F.W. Pollard Vice Chairman (Symposium)
D.G.W. Edwards (Seed Technology Workshop)

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D.F.W. Pollard, vice-président (Colloque)
D.G.W. Edwards (Atelier sur la technologie des graines)

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# WELCOMING ADDRESS

T.M. Apsey

*Deputy Minister of Forests*

*British Columbia Ministry of Forests*

Ladies and Gentlemen, Good Morning

It is my pleasure and privilege to welcome you to this meeting on behalf of the Province of British Columbia and the Ministry of Forests.

Yours is a discipline that demands commitment. It demands commitment from yourselves and it also demands commitment from every other facet of forest management. From government. From industry.

A tree improvement program cannot be considered on its own. It must fit, like the vital piece of a jigsaw puzzle, into the overall pattern of increasingly intensive forest management practices. The achievements of such a program are measured in the number of seeds coming out of your seed orchards, the hectares of land reforested with superior stock and, years later, the increase in wood harvested - wood from trees that grew bigger and reached maturity faster than they would have in a natural forest. Before we reach these goals, there must be a broad-based commitment to, and long-term support for, tree improvement.

I am told that it has been ten years since this association last met in British Columbia. There have been some important changes since that 1971 meeting in Prince George:

- A major commitment to intensive forest management has been made by both the Ministry and the forest industry.
- Our new Ministry of Forests Act, proclaimed at the beginning of 1979, paved the way for a revolving system of resource analyses and five-year plans.
- And in the field of tree improvement we have built on the foundations established by Dr. Alan Orr-Ewing in his pioneering work in coastal Douglas fir. Commitments now have been made to work in other important coastal species and the program has expanded to embrace the enormous potential of the Interior forests.

During this week you will see evidence of these changes for yourselves. But before you begin, I believe it will be a valuable exercise to examine the role of tree improvement within the context of the overall management process.

Ask a tree breeder how his program is going and you will get

back an enthusiastic response about the great potential for enhancing the forestry practices of the future. He works with the program day by day. He has no problem living with the inherent long-term nature of such a project. However, the silviculturists, the forest managers and the wood processors must also be looking to the years ahead. They, too, must be planning how best to take advantage of these long-term possibilities.

The fall-down effect — the realization that even if second-growth forests are managed intensively they will not produce the same volumes of wood that were available from the old-growth forests -- hangs over all of us. Our job is to deal with this shortfall. That will require all the tools and techniques the silviculturist has at his disposal -- choice of tree species, quick establishment, spacing control, possibly fertilization of forest lands. And underlying all this, as the true foundation, the genetic quality of the seeds we use.

The effects of using genetically-improved seed may take a long time to unfold but they are cumulative and their influence will be felt over the whole growth cycle and the eventual treatment of the crop. The actual cost of the seed is such a tiny fraction of the total crop value that additional investments to increase seed quality can be justified as money well spent, most particularly with those species that have a potentially high impact on wood supply.

Once there is a commitment to artificial regeneration and to planting programs, breeders can take steps to direct the crop towards the greatest return. Tree improvement practices will lead to assured seed supply and will influence the quality and quantity of wood produced in a given period of time. In this province, the move to more intensive forestry has been accompanied by the development of a co-operative approach. The work load for the total program is very large, even if you consider only the seed production function. By sharing that work with the forest industry, we are able to advance faster and more efficiently.

The province owns 94 per cent of the forest resource and the Minisry of Forests therefore holds the primary responsibility for managing the resource and ensuring the greatest benefit to the people of British Columbia. Some have referred to this arrangement as the "Big Brother Effect". I prefer to think of it as a true "Partnership". In any case, we have begun to share our responsibility with industry and the potential advantages of this partnership have already become evident.

You have heard about British Columbia's formation of a Coastal Tree Improvement Council. This body, made up of senior personnel from the Ministry and from major forest licencees, advises the Chief Forester on policy matters and actively works to strengthen the co-operative features of the program. Since then we have opened a program in the Interior and one of the first steps was to establish another organization: The Interior Tree Improvement Council.

The needs of this new program are already very large. For a start, the Ministry established an Interior target of 80 million improved

seedlings for 1995. For the province as a whole, the annual production target is 150 million improved seedlings by the year 2000.

These goals can be met only through a strong joint commitment by the minsitry and industry of both the tree breeding and seed production phases of the program. As recent evidence of this commitment, a new facility has been built at Vernon, to be officially opened in the near future. The Vernon Research Station and Seed Orchards will support the work of breeders and orchardists as well as physiologists and silviculture specialists who will provide much of the necessary knowledge and support. I hope by the time the CTIA comes back to British Columbia for another meeting, it will be able to meet at the Vernon centre. By then, too, the scale and scope of the Interior tree improvement programs will be closer to being on par with those on the coast. Indeed we expect the scale of the Interior programs will likely overtake the coastal commitments, despite the product value and high Mean Annual Increment of the coastal forests.

At present the emphasis of the Interior program is still on the interior spruces and lodgepole pine but some attention is being directed to the tree improvement potential in interior Douglas fir and western larch.

At the same time that we've been developing new initiatives in the Interior, we have moved to meet the increased propagation requirements for coastal programs through the expansion of research facilities at Cowichan Lake. The research station you will visit tomorrow is no longer just the home of the established program for coastal Douglas fir. The staff there is already involved in work on western hemlock and yellow cedar and in propagating Sitka spruce, amabilis fir, red cedar and other species. As part of the first stage of this expansion, 33,000 grafts were made there this spring. The staff and facilities are being built up. Clone banks are being established for all commerical coastal species to maintain the gene pool against losses through field exploitation. Similar developments are planned for the Interior at Vernon and Skimikin.

The work as you can see, goes on. We are making progress. But the main point I make today is this: tree improvement cannot supply fast answers: it needs a serious, long-term commitment. In British Columbia there is that commitment. Within our co-operative relationship with industry, the Ministry of Forests' Silviculture Branch spent $3 million in the last fiscal year on seed orchard establishment, maintenance, service projects and the selection of "plus" trees. In the current fiscal year the amount is increased to $3.5 million. These funds are in addition to the support given to the tree improvement section of the Ministry's research branch, where expenditures on breeding, provenance and research run at about the same dollar figure. Money, of course, it not the only commitment to be made, but you all know that having a firm, consistent fianancial base is an important part of laying the foundations for a stable, well-planned program on a useful scale.

The British Columbia Ministry of Forests is relying on tree improvement to play a vital role in helping to meet future wood supply goals. You people meeting here today provide welcome reassurance that we are not alone, that commitments are being made to tree improvement in other provinces, other nations. I hope the experiences shared at this convention will help all participants expand their knowledge and speed up the essential work they are doing in this field.

The prime objective of the Canadian Tree Improvement Association, as stated in your constitution, is "to promote the use of scientifically and technically sound genetic practices in Canadian forestry." To which I say: "Go to it".

# KEYNOTE ADDRESS

Roy Faulkner
Principal Geneticist
British Forestry Commission
Northern Research Station
Roslin, Lothian, Scotland

# KEYNOTE ADDRESS

# TREE IMPROVEMENT RESEARCH AND DEVELOPMENT - SOME THOUGHTS FOR THE 1980'S

Roy Faulkner

*Principal Geneticist*

*British Forestry Commission*

*Northern Research Station*

*Roslin, Lothian, Scotland*

## INTRODUCTION

I am indeed honoured to have been invited to speak to the Canadian Tree Improvement Association and I look forward during the meeting to seeing and discussing mutual problems with you all - and, at the same time, to learn some of your recipes for success. You should not assume, however, that my crystal ball is any bigger or better than your own - in many respects it is undoubtedly inferior.

Before warming to my main theme, which mainly relates to north-temperate conifers, it will be helpful, perhaps, if I outline briefly the responsibilities and current work of my team engaged on tree breeding which started in Britain in 1949 and where we have an expanding forest estate - the current area of which is some 1 3/4 million hectares. The annual programme of new planting is in the order of 24,000 ha with a further 8,500 ha of re-stocking.

My association with this tree improvement programme goes back 23 years during which period I have seen many changes in forest policy, attitudes, thinking, methodology technologies, and, like most others, have passed through the hoops of economic appraisals and financial constraints. All these have affected our breeding strategies which have the ultimate goal of maximising improved saw-timber production per unit-of-time. It is of some interest, perhaps, to note that our manpower resource (which currently consists of five graduates, eight technicians and support labour of eleven men), has remained almost static since 1963. Total funding, which is currently 450,000 C$ per year, has been kept broadly in line with inflation during the past decade. Nevertheless output per staff member has increased greatly due to ever-increasing experience; flexibility of management and job specification; a strong team spirit; integration and relationships with both forest manager and with our research colleagues in Silviculture and Physiology; by having only three well-located field stations; by having almost complete delegation of authority and control under one head; and by having responsibility for breeding research and development for both the private-and state-owned forestry sectors.

The research essentially applied but we have some involvement

in basic- applied projects. In round terms our annual capacity is: the survey of up to 1000 ha of plantations for registration as new seed collection areas and the resurvey of up to 500 ha of existing registered stands; making 10-12,000 grafts; designing and supervising the planting of 12 ha of new clonal or seedling orchards; making 7,500 isolations and artificially pollinating 20,000 flowers; raising 500 families (80,000 plants) and planting these in progeny tests on up to eight sites and up to 700 miles apart; and assessing an equivalent number of plants for height and stem form and a proportion for girth. Currently we have 38 ha of orchards of which 25 ha are 1.5 generation, 375 ha of progeny tests and 8,500 selected trees most of which are now under test.

In descending order of importance our species interests are: Sitka spruce, lodgepole pine, Scots pine, and Corsican pine (Pinus nigra var maritima). The hybrid between European and Japanese larches is also of importance and there is a growing interest in the hybrid between Sitka spruce and white spruce as a frost-hardy hybrid capable of growing well on very difficult sites in northern Scotland. Breeding effort and priorities are related broadly on a pro rata basis according to the importance of each species or hybrid. In addition to the main breeding programme we have established a number of research projects which aim to provide basic information to assist us in improving our strategies and techniques. Of these the more important ones have been: a plot-size and shape experiment; a population heritability study of 150 interbreeding trees representing all size classes; a complete diallel crossing-pattern of seven Sitka spruce trees; population studies of lodgepole pine and our own remnant native Scots pine stands using biochemical techniques; the development of standardised techniques for the assessment of experiments, mechanical data-handling and computation and interpretation of genotype x environment interactions, and a data bank.

On the international scene, and under the aegis of IUFRO, we have arranged and made a series of provenance seed collections of Sitka spruce, lodgepole pine, grand fir, noble fir and A. lowiana and have produced a handbook on seed orchards. In the early 1960's we were involved in launching the OECD scheme for the certification of forest reproductive material moving in international trade.

This sums up my experiences; it is against these that I present some thoughts on how I expect research and development in tree breeding to move during the next decade and which have relevance to some Canadian situations highlighted during the Petawawa Workshop of 1978.

The "crie de coeur" for more funds, staff and facilities is all too familiar; there are no glib answers for these matters which can only be realistically, if not always satisfactorily, settled by senior administrators and managers impartially discussing and firmly deciding how big the total research and development cake is to be over the next one or two decades, and how it should be divided. Johnston (1976) sets out some sound advice on the organization and management of forest research programmes and in particular he highlights the importance of retaining flexibility in staffing and producing long-, mid- and

short-term plans which are regularly updated.

Now let us consider some of the activities connected with a tree improvement programme, including some which currently are not so important but which we should bear in mind for the future.

## SEED SOURCES

### Seed Stands

Seed stand registration and seed certification schemes were organized and operated on a voluntary basis in Britain during the period 1956-73; there were three phenotypically-based categories. Despite several propaganda campaigns the schemes were not a success and although the 300 members paid lip-service to the objects of the schemes they never gathered any impetus. The reasons for failure varied but primarily were because: there was no established tradition of collecting conifer seed (other than from Scots pine): we were highly dependent on imports which were easy to arrange through merchants in north-west America, Europe and Japan; seed crops on seed stands of all but the pioneer species were unpredictable and infrequent, financial statistics and methods of assessing cone crops were unreliable; the physical difficulties of collecting seed by climbing; the stringent safety rules and practical difficulties of training and retaining seed collection teams as a unit from one year to the next - and - perhaps our misfortune to have imported the American grey squirrel into Britain instead of Tamiasciurus douglassii!!

In the mid-1960's it was becoming increasingly difficult to obtain lodgepole pine seed from certain Canadian and American sources which had been proven to have merit in origin experiments established in the 1930's. Furthermore, collections from some places were impossible to arrange, or, excessively expensive - for example - seed from certain Alaskan sources was quoted at 370 C$ per pound (820 C$/kg). For this reason over 100 ha of seedling seed plantations were established on sites well isolated from contaminant pollen and based either on a single proven superior origin, or, six unproven origins from a given seed region or zone. Where six origins were used they were planted concurrently with (or a year or two later than) origin experiments based on the same seed lots but established on forest sites. On the seedling seed plantation site each origin is represented by pure lines in each of many randomised blocks across the site. Inferior origins - determined on the basis of data obtained from the forest experiments - are removed and the plantation of resultant 'hedges' is then managed for seed production. The final plantation may consist of a single origin or 2 or 3 origins if there are no significant differences between them in the forest experiments.

This method is well suited to precocious flowering species, such as lodgepole pine and jack pine, and it quickly provides a reliable "home" seed source of proven desirable origin. It is inexpensive and easy to organize and each plantation provides an excellent base

population for intensive tree selection and further breeding work. Undoubtedly this method will be used in Britain well into the 1980's.

Seed Orchards

The initial concept of clonal seed orchards propounded by Syrach Larsen in 1934 was simple and in a wave of enthusiasm, which rapidly spread in the 1950's to the present date, tens of thousands of hectares of orchards have been established throughout the world. The most successful of these have been associated with pioneer species and amongst the conifers the pines in particular. Less satisfactory have been the sub-climax and climax species.

Amongst the many problems associated with orchards the most important are: ease of vegetatively propagating the ortets; root stock/scion incompatability; unpredictable flowering behaviour of selected clones in terms of amount and periodicity of flowering, sex ratio, period of female receptivity and pollen shedding, sexual compatibility, tolerance to selfing, and difficulties related to ground management, crop protection and cone harvesting. Many of these problems will remain with us for decades and many will, if ever, only be solved by local observation and experience. Because the number of variables involved is large and because most of them are the product of genotype x environment interactions, and because we are involved with a changing population of several hundreds of clones, it is obviously impossible to develop a satisfactory blanket prescription to cover all situations. Furthermore the scale of experimentation needed to solve or even shed light on some of the problems will require areas of ground far in excess of orchard requirements. Progress will mainly come about through painstaking detailed observations and recording over a long period such as the work on Scots pine flowering by Sarvas (1962) who pointed the way to the more recently reported observations by Eriksson (1978), on the analysis, interpretation and importance of temperature-sums on orchard productivity for Norway spruce, Scots pine and lodgepole pine.

From experiences in Scandinavia with the sub-climax species Norway spruce it is recognized that the location of an orchard can be of paramount importance for regular and heavy cone production. In general orchards located to the south of and at lower elevations than the site of the original natural population encourages heavier flowering - probably as a consequence of higher accumulated temperatures and perhaps coupled with higher moisture stress associated with lower rainfall and higher transpiration losses by the ground cover. For these reasons the Danes have already arranged for a Douglas fir orchard to be established in southern France, to give them a shift of 12 degrees to the south in order to achieve heavier and regular flowering. Undoubtedly other countries with similar problems will increasingly seek to cooperate in this way in the 80's. However, further investigations of the effects of plant development from seeds derived from parent material growing in a totally different environment to the original parents are needed to support or modify Bjørnstad's (1981) findings that local environmental effects, for example photoperiod may modify growth rhythms and give rise to

biochemical changes in grafts which may be transmitted by cytoplasmic inheritance.

Mini-intensive orchards grown within plastic-skinned greenhouses have been successfully used for several years in Finland. They are ideal for the mass-production of small-seeded precociously flowering broadleaved trees such as birch and alder, but their general suitability for conifers is very much less because of the lower attainable seed yields per unit of floor space. Furthermore several successive crops of grafts are needed since the life of a graft, grown intensively under these conditions, is unlikely to exceed 4-5 years. Nevertheless such orchards provide opportunities for mass artificial-pollinations when the aim is the regular production of very valuable hybrids for vegetative mass-propagation schemes. Double the quantities of seeds might be obtained if containerised stock can be raised on pallets for easy mechanical shifting into and out of the orchard "house". Because of the earlier growth and consequent earlier date of flower initiation it should be possible to induce two flower crops per season - one on each of the two successive graft crops.

Normal seed orchards are wasteful of space - particularly in the formative years and the intensity of thinning and periodicity of thinning has to be carefully planned to optimize seed production throughout a rotation. Similar problems have arisen in top-fruit orchards where intensive management of the crowns by regular pruning occurs. More recently development has swung towards growing cordon "maidens" for 3-4 years before clearing the crop and restarting. In shy-to-flower conifers it seems inevitable that more intensive research should be undertaken to control the shape and height of orchard trees and to manipulate the angle of branching in ways which will promote flowering and produce the maximum number of easily accessible flowering-sites/per tree. Perhaps orchardists will begin to renew and reconsider the work reported in the 1950's and early 60's which aimed to develop more potential flowering sites by judicious partial crown removal and pruning for spruce (Nienstaedt 1981), and cordoning, by intensive crown-training to produce "flat" tree forms in, for example, larch.

New ideas should be tried such as those produced by Sweet et al. (1978) who discuss bi-clonal orchards based on parents with exceptionally high specific-combiningability and the use of supplemental mass-pollination; the use of growth retardants; and use of both chemical and mechanical methods of inducing flowering; and flexible designs (Bell et al. 1978). Good progress has already been made in these fields and must be pursued further.

To those involved in research I make the following pleas: to those working on flowering - report the number of potential flowering points per unit of crown when presenting your flowering data; to those applying fertilizers - report the levels of nutrient elements in the rooting zone of the soils before your fertilizer applications are made - in order to indicate the starting fertility levels; to those providing irrigation data and flowering responses provide data on the soil water

potential at more than one depth - using tensiometers and, when feasible, the plant water potential from pressure-bomb measurements - together with a record of the ground vegetation and its management.

## RESEARCH AND DEVELOPMENT OBJECTIVES

Published objectives of most breeding programmes are: to increase yields, or, to raise the harvest index and produce higher quality timber (Namkoong et al. 1980); the increases arising from speedier establishment of the young crop and faster rate of height and diameter-growth, and the higher qualities of timber deriving from having straighter and more circular stems and finer branching. Only occasionally are the factors of total dry-matter production per unit-of-volume of the saleable stem-wood, cell wall-thickness, fibre lengths, or proportions of spring-wood to autumn-wood referred to - yet all of these are of great importance when defining conifer wood quality. It is my firm opinion that tree breeders will shortly be forced more and more into looking critically at the end-product - wood - rather than continuing to place emphasis on the easily assessed phenotypic characters of height, girth and stem- straightness.

Many years ago cattle breeders in Britain selected and bred animals "for the show-ring" - concentrating their efforts on width of forehead, symmetry of horns, coat color, etc; they paid scant attention to milk yield and its butter-fat content with consequences which took a long period to rectify. We must profit from their negligence and ensure that similar errors are not repeated in our programmes, so that due to indirect selection we produce crops with unacceptably low wood-density, or, timber with undesirably short fibres.

## FOREST MANAGEMENT AND TREE BREEDING INTERRELATIONSHIPS

### Timber Quality

The use of mechanical stress-grading techniques on sawn-timber is rapidly increasing. From data so far obtained it can be generalised that spruce timber of even-growth, and grown at a rate equivalent to an annual production of more than 14 $m^3$/ha/ann, may produce timber below the top grade (MS 75) standard. The weighted British national average yield-class for Sitka spruce, for example, is 12 $m^3$/ha/ann and lies within a range of 6-24 $m^3$/ha/ann, thus it is probable that a substantial proportion of timber inferior to grade MS 75 will be produced unless through selection and breeding, the breeder can substantially improve timber strength- properties.

As a consequence British foresters are now reconsidering some of their silviculture and management practices and particularly those concerned with plant espacement, improving survival, inputs of fertilizers, and later thinning regimes - all of which interact and have significant effects on sawn-timber quality and its value. However,

Cannell (1978) points out that many breeders tend to select progenitors of crops which are adapted to grow well on a variety of sites, under a range of climates, using current site preparation and forest management techniques; and without really considering more intensive cultural treatments including high fertilizer inputs which assist crops to speedily capture the site and establish a full canopy quickly. Obviously there are conflicts of opinion on the basic silvicultural techniques to be applied to those species and in those situations where faster growth, without some compensatory higher autumn-wood/spring-wood ratios, or, an overall increase in wood density, could have commercially-important harmful effects in the longer-term. Clearly it is essential to critically examine wood samples taken from progeny tests on a variety of sites in order to establish the genetic and environmental components of variation to the total phenotypic variance and to establish the importance of any gene x site interactions. Nicholls et al. (1980) recently provided a model report on wood factors to be considered and how the data should be treated.

Speculation on the pro's and con's of fast-grown timber, the possible loss in dry matter resulting from indirect selection due to negative correlations between ring width and density and the narrow-sense heritability estimates for the more important wood characters, will not be settled until breeders, silviculturists and economists begin to interact more effectively themselves.

Ideotype

On certain sites and particularly on marginal sites at higher latitudes, future management may be directed towards the establishment of forests which are grown to rotation age with minimal thinning or even no thinnings at all. This problem is already being discussed in Finland (Karki 1980) where the debate centres on whether or not to select and breed ideotypes (ideal plant types) with long, narrow crowns which can be grown to maturity with only one or even no thinning. Landscape gardeners have used selected ideotypes to good effect over many centuries and the challenge of selecting and breeding forest tree ideotypes for special forestry purposes must not be overlooked and, perhaps, more so for those species which can be easily and cheaply propagated vegetatively. Several important advantages are claimed for columnar narrow-crowned trees, such as: improved stem quality, stem-wood percent, saw log percent, and value per unit of timber: fewer plants and lower planting costs: reduced needs for early economic thinning, cost of limbing, transport and processing (and associated energy needs); and higher resistance to storms and snow. The chief disadvantages are higher establishment costs and smaller mean stem diameters from the final fellings. Certainly the time is ripe for the establishment of well-designed experiments to provide indications of the most effective ideotypes and/or ideotype mixtures for different situations, their the financial benefits, if any, and of certain ideotypes in silviculture and management techniques and on wood volume production and quality.

Nutrient Requirements

To enhance tree growth, fertilizers are now commonly and in some case repeatedly applied as a routine forest management practice, but the recent very sharp increases in fertilizers and their application costs are now causing managers to reconsider their policies. Between-family responses and interactions to different fertilizer inputs have been clearly demonstrated for many tree species but mainly in pot and nursery experiments. The rewards for developing tree varieties which perform well under minimal nutritional regimes should be high and it is now timely for breeders and nutritionists to jointly design experiments for screening trees of low soil N, P and K fertilizer regimes throughout a rotation. Such projects will be costly in terms of land, the provision of plants, maintenance and assessment costs and particularly if both seedling families and clones are tested over a range of environments. It is essential for tree breeders to think boldly and provide adequate research material for their successors even though this creates "hiccups" in their annual breeding programmes - which in many cases have become rather stereotyped now that strategies and reliable breeding techniques have been developed and introduced.

## RISK FACTORS

Foresters are usually very cautious, largely because their training and the long life-cycle of their crops make them aware of their responsibilities to succeeding generations. Recently this awareness has been sharpened by the overtures from the gene-ecologists, conservationists and the economists who predict world-wide timber shortages in the next century. During their training many foresters, and particularly the more senior ones, have been influenced by European silvicultural practices which until fairly recently were often based on natural regeneration and crops of mixed species and ages. Even today the extremists shun the thought of changing to more productive species or origins, and the idea of monocultures and large areas of even-aged forests are abhorrent to them. It seems inevitable, however, that from a purely economic point of view that much of the world's future wood will be derived from plantations of pure species, and probably more productive exotic species planted to produce a mosaic of pure stands.

Choice and Use of Seed Origins

Once the decision to change species has been made the question of choice of seed origin arises immediately and the testing of different origins for adaptive traits becomes a major research task. Unless the area of the origin selected for testing is prescribed and then adequately and carefully sampled, any results obtained from the comparative tests may be inconclusive. Ignoring this basic requirement in some research and development programmes has led to very many wasted years and today there can be no excuse for repeating these errors. Due to physical and financial limits it is always impossible to adequately sample a species range, or zone within a range, and the variation in performance between origins is often high and often higher still within origins. Similarly

it is impossible to adequately sample the sites on which the material may be planted commercially. Experimental data therefore should be very thoroughly examined and should always include a critical examination of within-plot variation before reaching major decisions. Where experimental data from origin experiments show no clear-cut answer, it makes sense to encourage the use of mixed origins in commercial practice - mixing two or more seedlots of those origins where the rate-of-growth and stem quality is likely to meet the potential needs of the user within the region or zone in question. Samples of each origin can usefully be kept separate and planted in pure plots of upwards of 5 ha for further research and/or general confirmation of many experimental tests results. In future years the best of these sources may give an additional bonus by providing a suitable and sizeable "home" seed source.

Use of Planting Stock Derived from Orchards

Breeders in the north temperate regions are now at the stage where they have established and are collecting seed from multi-clonal orchards based on untested clones. As yet few have established orchards based on tested clones and these are mostly confined to precocious flowering pioneer species. The untested orchards are normally based on clones derived from a single phenotypically superior stand, a forest, or a region, and few contain more than 40 clones; many are based on only 20-30 clones. By the time those clones with very early, very late or even lack of flowering have been rogued or discounted such orchards will have a much reduced or very narrow effective genetic base and the risk of inbreeding through selfing may be high. The risk factor to the manager using material from such a source is unknown and will vary in an unpredictable way from orchard to orchard. The gain from using seed from such orchards may be high, but it could be negative depending on circumstances. The question arises how should the seed be used during the period until 1.5- and second-generation orchards based on tested clones begin to bear fruit? Again I would suggest that mixing seed or plants derived from different orchards, based on clones from the same zone or even in some cases adjacent zones where phenotypic variation across an artificial boundary between zones or regions is continuous, should be seriously considered. National seed certification schemes and regulations intended to protect the purchaser by guaranteeing trueness of species, variety and origin or provenance should, at this stage in our development, include a clause to permit mixing of lots providing the accompanying certificate accurately describes the material. If it is mixed then the certificate should clearly indicate the components and proportions of the components in the mixture.

Clonal Planting Material

There are great economic attractions for clonal plantations, mainly because these allow the breeder to take advantage of the highest genetic gain from heterosis, rare combinations, useful aberrant forms, aneuploids and polyploids and to get these into commerce far more quickly than through the tested-orchard approach - thereby enhancing the all important genetic gain per unit-of-time. In a spruce breeding programme

it normally takes 12-14 years from the year of pollination to the completion of a progeny test - two more years to provide a graft - 10 more years before the first commerical quantities of seed are available from the orchard - and a further five-ten years before achieving full orchard seed production, i.e., approximately 30-35 years. Assuming a genetic gain of 15 percent the mean annual gain is only half a percent! In contrast one seedling from a desirable controlled cross can be cloned-up to yield say 500 plants within five years, which equates to 10-15000 plants per hand-pollinated flower or up to 1 1/2 million plants per thousand cones five to seven years after a pollination. This is equivalent to a mean annual gain of 2 1/2 - 3%! These are compelling statistics and certainly must have considerable impact on our long-term policies and expansion plans for orchards.

The risks of failure of plantations based on a single clone are unpredictable and cannot be quantified. Some forestry organizations have taken such risks and, for example, Destremaux (1980) refers to 250,000 ha of poplar plantations in France of which 75 percent consist of clone I214 robusta, and of four centuries of clonal forest practice in Japan with Cryptomeria japonica. Pomologists have taken similar risks, and by 1980 it was estimated that some 10,000 million Golden Delicious apple trees derived from a single seedling selected in Virginia in 1914 have been cultivated. However evidence from agricultural crops clearly suggests that the risk of loss or debility from attacks by pathogens or insects must be much higher from a single than from a mixture of clones, which Tigerstedt (1974) suggests should be used in tens rather than just a few; Kleinschmit et al. (1977) recommends over one hundred. Heybroek (1978, 1980) points out the need for genetic variation (which will not preclude disease damage) to limit the impact of a disease by spreading the risk and by compensation when mixtures are used.

Clone mixtures are expected to show less phenotypic variation than single clone cultivations and should be more reliable ecologically and particularly with regard to host-parasite systems; if combined optimally they should out-perform pure cultures. It was suggested (Stern, 1969) that a major task for tree breeders should be the selection of optimal clone mixtures. I think it is doubtful that such a project will ever have a substantial pay-off since breeders are expected to produce a continuous stream of new and better clones. Thus by the time satisfactory mixtures of the first batches of the ten-prevailing best clones have been determined and "commercialised" they will, in all probability, have been superseded by others of greater potential merit.

In some rather elementary comparisons of growth data made on seedling and single clone forest plantations the coefficient of variation of the former was calculated to be 65 percent whereas in the latter it was 15 percent - again a powerful argument indeed for clonal plantations. But - who could really say what fraction of the 15 percent was attributable to clonal drift rather than environmental variation?

In horticulture searching for useful mutation has been a passive occupation in the past and today some fruit tree breeders are now

encouraging slight changes in their clonal stocks by the controlled use of mutagenic agents - aiming to secure, by chance, unaffected fruit qualities but perhaps higher resistance to pests and diseases. This is an approach to improvement which could be pursued by tree breeders when, having obtained a vastly superior clone by regular selection and breeding methods, they could then introduce minor genetic variations, having no effect on say vigour or stem form but which could provide improvements in disease resistance or rooting qualities. There is at least a case for exploratory investigations in this field in order to develop methods and techniques for achieving minor mutations in tree bud and cutting material.

Whilst on this subject one should also mention the risk, again unquantifiable, associated with cytological instability arising during cell and callus culture, particularly, perhaps, where chemical stimulants are used for rooting or encouraging re-juvenation. There is also a probability of producing some chimaeras arising from meristem cultures, or, root chimaeras from rooted cuttings. As research and development in these fields is pursued, it is essential for breeders to make detailed observations on the plantlets produced and their subsequent performance.

## PROBABLE IMPLICATIONS OF SOME RECENT TECHNOLOGIES

### Vegetative Propagation

Rooting pine, spruce and larch cuttings has been intensively researched during the past three decades. Most workers have reported large between-clone differences in rooting ability, a rapid decrease in rooting ability with age of the ortet, and difficulties in satisfactorily weaning the resultant rooted cuttings. Stock plants under three to six years of age are preferred for the commerical production of cutting material in order to achieve high rooting success and to minimize topophysis and the frequently associated plagiotropism. This poses a serious dilemma since breeders usually wait 8-10 years before deciding which progenies under tests have sufficient merit to warrant propagation, an age at which any selected tree can no longer be satisfactorily used as a stock plant for cuttings. As a result the only real options are to resow some of the original seed to produce stock plants for propagation whilst it is still very juvenile, or, to create a new batch of seed by repeating the appropriate specific crosses and then to resow. However a very useful option may soon become available if a promising technique, under development in the research department of the French Organization 'Association Foret-Cellulose', proves successful. The method involves four cycles of re-propagating very old plants (in their case 400-years-old P. pinaster trees) by means of grafting. After the fourth cycle complete re-juvenation of the material appears to have occurred and rooted cuttings with primary needles have been obtained. The problems of maturation and how to reverse it, and methods for the detection and measurement of juvenility, are of enormous importance to all plant propagators and conifer breeders and it is in this field of investigation that our colleagues in physiology and biochemistry have such an important continuing role to play.

Variation between $R_1$ and $R_2$ generations of P. radiata have already been noted by Shelbourne et al. (1974) and as they rightly point out these could have wide implications in clonal selection programmes. It must also be accepted that both genetic and non-genetic causes may affect early performance and therefore the speed of establishment of clonal crops. Clearly the field for further investigation is large and of major importance (Lindgren, 1977; Morgenstern, 1980).

Tissue Culture

Probable practical applications and problems of tissue culture in forestry have been listed and briefly discussed by Winton et al. (1976), Bonga (1977) and Reinhart et al. (1977) from which it is clear that tree physiologists have much work ahead of them before the very large problems associated with embryogenesis and organogenesis are solved. Furthermore, the reported incidence of chromosomal abnormalities in gymnosperm cultures is strongly indicative that this is unlikely to be a practical technique for conifers. Organic chemical compounds, and terpenoids and phenolics in particular, may be responsible for adverse growth and survival of tissue cultures in pines and spruces. Current research in Sweden is aimed at the reduction or inhibition of excess phenolics (Erikson et al. 1980). A technique for loblolly pine has been recently published by Mott et al. (1981).

Haploid Culture

The load of deleterious genes carried by many conifers is perhaps the largest deterrent to pursuing research in the development of haploid cultures from the readily available and bulky megagametophytic tissues. Coupled with this are the reported difficulties of getting haploid tissues to differentiate during culture and again there is a risk of mutations occurring; these three factors suggest that this particularly difficult field of research should not be actively pursued at the moment.

Protoplast Hybridisation

Hybridisation of somatic or haploid protoplasts is being researched in several plant genera of commercially important plant species. Success has already been achieved in both potatoes and wheat - two crop species for which much is already known about their genetic composition. It seems unlikely that tree breeders will enter this field until they have a much better understanding of the genetics of the individuals they wish to combine. In the meantime geneticists and tree physiologists should not be discouraged from investigating and developing suitable techniques for future application in both conifer and broadleaved species since protoplast hybridisation could have much to offer tree improvers in the future.

Gene Manipulation

This is concerned with the formation of new combinations of

heritable material by the introduction of nucleic acid molecules from an outside source into a virus, bacterial plasmid or other vector system, and to allow their incorporation into a host organism in which they do not naturally occur but in which they are capable of continued reproduction. It requires very sophisticated techniques in which fragments of DNA are first attached to a suitable vector. At present suitable vectors for higher plants have to be discovered but the DNA plant viruses and the Ti plasmid of Agrobacterium tumefaciens appear to be the two most probable candidates (Old et al. 1980). Since conifers are generally devoid of viruses there seem to be little hope for the first method but the Ti plasmid of A. tumefaciens may have a future role for some hardwoods. A 1978/79 Delphi study made no mention of a recombinant DNA break-through in forest trees but did suggest a high probability of the development of new nitrogen-fixed plants by the year 2000 (Stewman and Lincoln, 1981).

Genetic engineering research and development programmes are extremely expensive and are associated with many technical, organizational, staff and financial problems. In Europe it is now acknowledged that the budget needed to initiate and bring to term research and development in a molecular biology project tends to exceed the capabilities of a single institute. For this reason alone it seems highly improbable, both now and for several decades ahead, that tree improvement work in this field can be adequately and justifiably financed for what is very speculative research.

Biochemical Studies

To date these have had little impact on the management of forest resources but they have contributed to our understanding of the spatial and temporal dynamics of populations (Forrest, 1980a). In tree breeding programmes chemical features offer a possible sound method for monitoring progeny selection and testing programmes. There are two possibilities for research into factors responsible for chemotypic variation. First, investigations into the secondary products, for example, monoterpenes and polyphenols, which are important in themselves, since certain chemotypes have been naturally selected in different areas of the natural distribution (Forrest, 1980b). In this case chemotypic variation may be used for selecting trees if the characters are commercially important, for example, disease or insect resistance. Second, they may be directly selected by linkage association with other directly selected characters (Weissenberg, 1976).

Monopterpenes could be used for refining the description of natural geographic variation and therefore are likely to be used for seed certification purposes - using, in certain species perhaps, seed coat terpenes (or polyphenols) in addition.

Inheritance patterns will require investigation for the main commercial species and, when completed, could perhaps be used for monitoring hybrid-origin programmes.

Polyphenols

Polyphenols have a possible role to play as indicators of heartwood quality in relation to resistance to rot and in hardwood variation studies where resins are absent. The part that polyphenols play in resistance to browsing or insect damage should not be overlooked and, if there is a link, it would provide a most valuable tool for indirect selection.

Isozymes

A greatly increased understanding of isozyme variants within populations is required in order to determine the ecological significance of allelic variation; for example, different alleles may have different optimal temperatures for activity, in which case metabolically important enzymes could be used for selecting trees best adapted to growing under different climates. For these reasons there needs to be an extension of the enzyme system which can be conveniently analysed to include those known to be involved in controlling photosynthesis, respiration, and the synthesis of secondary products which are accumulated and locked-up to form energy reserves.

Much research is required to establish relationships between the different biochemical approaches and to determine which are best for variation studies and which will give evidence. At present it appears that isozymes are of limited value in studies of natural geographical variation but they are likely to have greater relevance in monitoring individually selected lines where distinctions are relatively 'fine' and in progeny-testing programmes.

Gentotype x Mycorrhiza Interactions

In the mid-1970's the mycorrhizal fungus Pisolithus tinctorius when compared with other mycorrhiza-forming species was reported to enhance the growth of loblolly pine seedlings (Mar[illegible] et al. 1979). This suggested that it might be possible to screen mycorrhizal fungi for effectiveness as symbionts and so, perhaps, grow large seedlings and perhaps even trees to rotation age more quickly. Recent observations, however, have shown that different mycorrhizal species and mixtures of species occur at different developmental stages of a tree crop and also that the benefits may be highly dependent upon the levels of available soil nutrients.

Despite the difficulties of identifying mycorrhizal fungi and establishing and culturing pure strains, it does seem worthwhile to research this field for a longer period. During the process of vegetative propagation by cuttings it should be possible to exercise a much greater influence on mycorrhizal associations than is possible by raising seedlings and transplant stocks in normal nurseries, in the same way that associations can be influenced during containerised seedling production. If this proves to be so then investigating the interactions between tree clone x mycorrhizal species x mycorrhizal strain should

quickly demonstrate the potential value and importance of further research in this field. It is interesting to speculate that in routine progeny tests some of the rapid changes in ranking for vigour between individuals both within and between plots, and especially in the early years, may be due, partly to mycorrhizal species or strain changes and their interactions with each tree genotype, and partly to seasonal macro- and micro-climatic effects.

## CONCLUSION

When I was invited to prepare this address my remit gave me plenty of latitude - and as a result I have had to treat most of the material quite sketchily and to leave many topics without comment at all. Perhaps during our time together over the next few days we can make the opportunities to discuss some of these matters more fully. Nobody ever got a quart out of a pint pot nor did anyone run satisfactorily before he could walk. In the formative years of a tree improvement programme there is a real danger of trying to emulate the work of breeders of agricultural crops and of trying to keep apace and use new technologies and methods for which we are ill-equipped to do. Tree breeding is, and always will be, a long-term activity and, despite all the words of wisdom which have been written and spoken in the last 20 years it must, in practical terms, remain a very imprecise art for several decades to come. Only after the broadsword has been used, albeit crudely, to reduce the breeding base-populations to a manageable size, can tree breeders and geneticists hope to get out and use their scalpels to refine existing and newer techniques to real effect. The tempo and order in which this is done depends on many things but foremost is the available resource both in terms of personnel and its quality, and money. Because the turbulent 80's are likely to be affected by financial instability and strigency any aimless meandering by R&D staff must not be condoned.

The common goals of increased volume production coupled with increased value, lower costs and minimal losses are very clear but the route to them is still hazy. For this reason we must retain a degree of flexibility and adaptability so that we can mould to changing patterns as they emerge and this can only be done by being opportunist and quick off the mark and by taking things forward technologically in a pragmatic and tactical manner.

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## SEED ORCHARDS

Chairman:

Mike Crown
British Columbia Ministry of Forests
Duncan, B.C.

# THE SEED ORCHARD PROGRAM IN BRITISH COLUMBIA

R.C. BOWER

*Forest Geneticist*

*MacMillan Bloedel Limited*

*Nanaimo, B.C.*

## ABSTRACT

The majority of seed orchards in British Columbia are developed under the auspices of two (Coastal and Interior) Tree Improvement Councils. Priorities are identified by each Council, while design and management guidelines are set by Technical Planning Committees. Coastal orchards are invariably clonal, produced mainly by grafting; graft incompatibility has not been a problem. The major management considerations of site selection, root pruning, insect control and the phenological control, supplementation and collection of pollen are outlined. The 25 coastal orchards established or planned for 7 species and 9 orchard planning zones, and 9 proposed orchards are briefly described.

## RÉSUMÉ

La plupart des vergers à graines de la Colombie-Britannique sont exploités sous l'égide de deux conseils d amélioration des arbres: l'un pour la région côtière, l'autre pour l'interiéur. Chacun des conseils établit des priorités, tandis que les comités de planification technique émettent des recommandations pour ce qui est de la conception et de l'aménagement. Les vergers côtiers sont toujours de type clonal et ils sont établis surtout par greffage; il n'y a pas eu de problème d'incompatibilité des greffes. On donne un aperçu général des principaux aspects de l'aménagement: le choix de la station, l'élagage des racines, la lutte contre les insectes, ainsi que le contrôle phénologique, l'amélioration et la récolte de pollen. On fait une brève description des 25 vergers côtiers déjà etablis ou qu'on se propose d'établir pour 7 espèces, de 9 zones proposées pour des vergers, ainsi que de 9 vergers proposés.

## INTRODUCTION

The majority of seed orchards in coastal British Columbia are managed or being developed under the auspices of the Coastal Tree Improvement Council (C.T.I.C.). This is a government-industry cooperative tree improvement program. Its history and development have been well documented elsewhere (Crown 1979, 1980). Recently an Interior Tree Improvement Council (C.T.I.C.) has been formed to serve the same function in the interior of the province.

Twenty-five seed orchards are established or planned for establishment by the coastal cooperators (Table I). These orchards will cover seven different species (F, Hw, Ba, Cr, Cy, Ss, Se)[1] and nine seed orchard planning zones (Figure 1).

An additional nine orchards are proposed for the coastal portion of Prince Rupert Region. These orchards would cover five species (F, Hw, Pl, Ss, Sx)[1] and four seed orchard planning zones (Figure 1).

To arrive at priorities for the establishment of seed orchards, questionnaires were sent in 1979 to both government and industry forest managers. The managers were asked to outline their planting programs and species preferences in 1979 and to project these figures to 1994. The projected figures for 1994 were compiled and used by the C.T.I.C. to arrive at priorities for seed orchard establishment.

A Technical Planning Committee (T.P.C.) was formed to provide technical input to the establishment and management of seed orchards within the cooperative. The T.P.C. is made up of breeders and tree improvement personnel from the British Columbia Ministry of Forests (BCMF) and industry.

After the C.T.I.C. had established the priorities for seed orchard development, the T.P.C. set guidelines for the number of clones each orchard should contain, estimated seed yields to determine orchard sizes and general establishment and management principles.

The C.T.I.C. seed orchards will be established at nine seed orchard complexes. Four of the complexes will be managed by the BCMF and

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[1] F - Douglas-fir - Psuedotsuga menziesii
Hw - Western hemlock - Tsuga heterophylla
Ba - Amabilis Fir - Abies amabilis
Cr - Western red cedar - Thuja plicata
Cy - Yellow cypress - Chamaecyparis nootkatensis
Ss - Sitka spruce - Picea sitchensis
Se - Englemann spruce - P. engelmanii
Pl - Lodgepole pine - Pinus contorta
Sx - Interior spruce - Picea spp.

Table 1.

## CTIC SEED ORCHARDS

### TARGET AREA

| No. | AGENT | SPECIES | ZONE | ELEVATION (m) | SEED TARGET (kg) |
|---|---|---|---|---|---|
| 1 | MoF | F | EVI | 300 - 700 | 38.3 |
| 11 | Tahsis | F | WVI | 0 - 600 | 20.8 |
| 14 | MoF | F | SCM/CIT | 300 - 900 | 22.4 |
| 15 | MoF | F | JS | 0 - 450 | 19.8 |
| 16 | CFP | F | EVI/JS | 600 - 900 | 20.5 |
| 18 | Tahsis | Ss | WVI/NVI | 0 - 900 | 3.8 |
| 20 | MoF | F | CIT | 760 - 1070 | 52.4 |
| 26 | WFP | Hw | NVI/WCC(s) | 0 - 450 | 2.9 |
| 27 | WFP | Hw | NVI/WCC(s) | 450 - 900 | 1.8 |
| 28 | WFP | Cr | NVI/WCC | 0 - 600 | 0.9 |
| 29 | BCFP | Ba | WVI/JS | 0 - 450 | 40.6 |
| 30 | BCFP | Hw | WVI | 600 + | 4.4 |
| 31 | MoF | Se | CIT/SC | 1100 - 1500 | 11.4 |
| 32 | MB | Hw | WVI | 0 - 450 | 2.9 |
| 33 | CFP | Hw | JS/SCM | 0 - 450 | 1.3 |
| 34 | CZ | F | JS | 0 - 450 | 21.7 |
| 35 | MB | Ba | EVI/SCM | 900 + | 31.7 |
| 36 | Tahsis | Hw | WVI | 0 - 600 | 1.3 |
| 37 | MB | Cy | SCM/CIT | 700 - 1200 | 3.2 |
| 38 | CZ | Cy | WVI/EVI/JS | 600 - 1200 | 3.2 |
| 39 | MB | Cr | WVI | 0 - 600 | 1.6 |
| 40 | CZ | Cr | EVI/SCM | 0 - 600 | 0.5 |
| 41 | MoF | Ba | SCM/EVI/JS | 450 - 900 | 27.5 |
| 42 | WFP | Ss | QCI | 0 - 450 | 3.5 |
| 43 | MoF | Hw | JS/SCM | 450 - 900 | 3.0 |
| R-1* | | Sx | T | 450 - 900 | 4.9 |
| R-2* | | Ss | NC | 450 - 900 | 2.7 |
| R-3* | | Ss | MC | 0 - 450 | 2.2 |
| R-4* | | Ss | QCI | 450 - 900 | 2.2 |
| R-5* | | Ss | NC | 0 - 450 | 2.0 |
| R-6* | | Pl | T | 450 - 900 | 3.1 |
| R-7* | | F | MC | 0 - 450 | 4.8 |
| R-8* | | Hw | NC | 450 - 900 | 2.0 |
| R-9* | | Hw | MC | 450 - 900 | 2.0 |

* Proposed New Orchards.

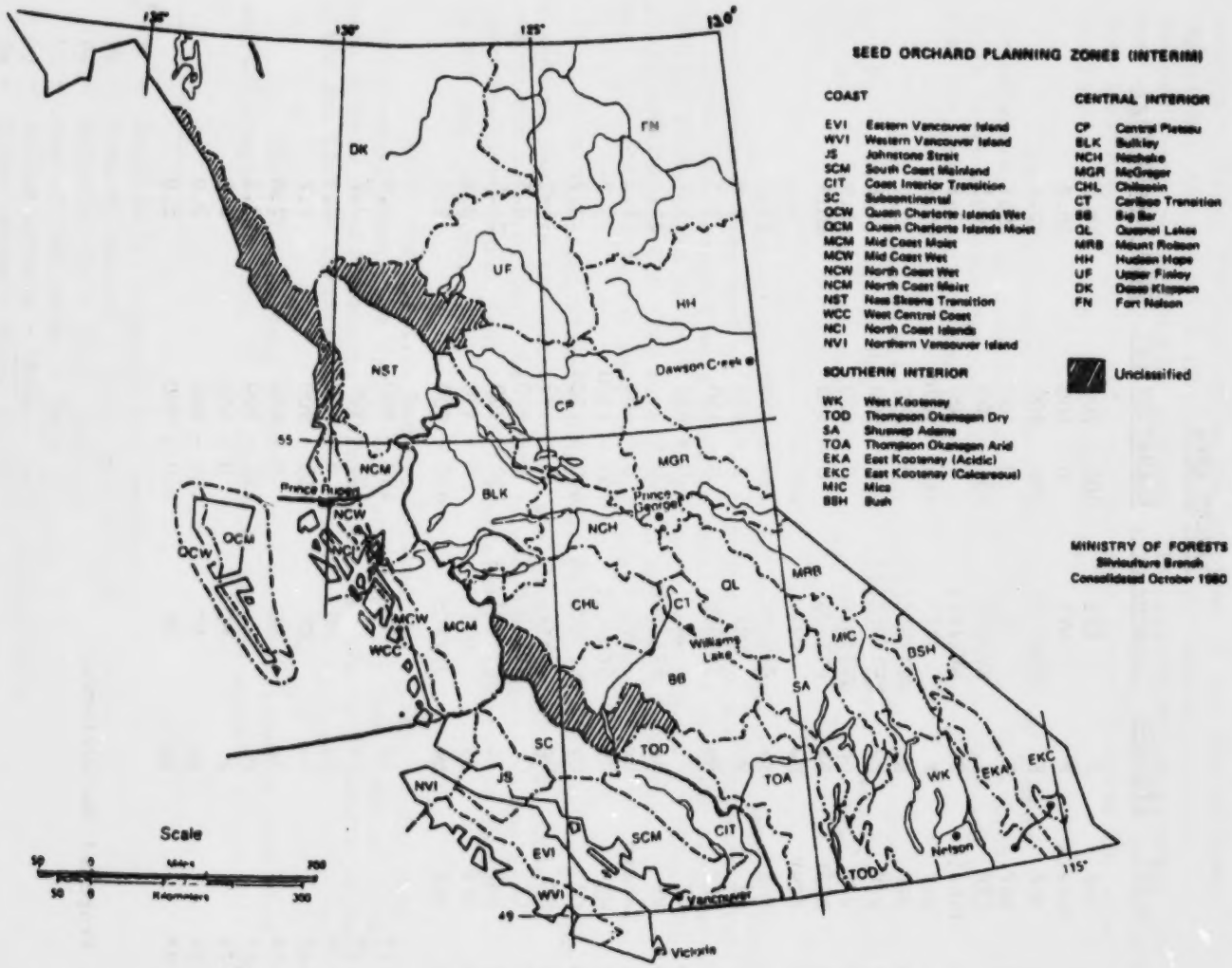


Fig. 1. Seed orchard planning zones.

five by Companies. Each seed orchard manager prepares a composite working plan according to a standard format for the seed orchard complex under his/her management. This plan serves as a working document. It is revised annually and reviewed by a five-six member Technical Review Committee. The Technical Review Committee is comprised of the seed orchard coordinator, BCMF breeders and two industry representatives.

## SEED ORCHARD MANAGEMENT

Seed orchard management in British Columbia is still in its infancy since most orchards are in the establishment phase.

All of the C.T.I.C. orchards will be clonal. Parent tree lists are prepared by the seed orchard manager and approved by the T.P.C. Permutated neighbourhood or randomized complete block (with restricted randomization) designs are being used for the C.T.I.C. orchards.

Most of the clonal material will be reproduced by grafting. Limited amounts of hemlock, cedar and cypress will be reproduced as rooted cuttings. Most of the propagation for coastal seed orchards will be carried out at the Cowichan Lake Experimental Station. New facilities have been constructed for this purpose.

Based on our current level of knowledge, graft incompatibility does not appear to be a problem in any species except Douglas-fir. The BCMF is carrying on an intensive screening and breeding program for the purpose of producing highly compatible Douglas-fir rootstocks.

Past experience in seed orchard management has shown the importance of orchard location in relation to cone production. Areas experiencing summer drought are now considered prime areas for seed orchard establishment. From 1963 to 1979 some 25 seed orchards were established on the coast; 65% of the total seed produced has been by the four seed orchards located in areas of summer drought (Crown 1980).

Root pruning, using a large (44") tree spade, has proven to be an effective method of inducing cones in Douglas-fir orchards on the fringe of the summer drought areas. In one test Karlsson (1977) reported a five-fold increase in cone production from root pruning. Filled seeds per cone was the same for treated and control.

Phenology data and pollen flight data are routinely collected in most seed orchards. Since most of the present Douglas-fir orchards are established in close proximity to natural stands, pollen contamination is a very real problem. One method of overcoming this problem is the use of solid set irrigation systems. The concept of using the cooling effects of water spray to delay reproductive bud development was the first reported by Silen and Keane (1968). In a more recent paper, Fashler and Devitt (1980), reported that cooling successfully delayed 76% of the clones in Pacific Forest Products' seed orchard past the peak pollen flight period.

An added benefit of reproductive bud delay is the possibility of some insect control. Miller (personal communication[1]) reports that if buds can be delayed by ten days, reasonably good control of the Douglas-fir cone gall midge (Contarinia oregonensis Foote) can be achieved. The process is quite weather dependent and insecticides remain the most effective method of control.

Supplemental pollination is frequently practiced due to the pollen contamination problems, young orchards producing inadequate quantities of pollen, and a desire to influence the genetic structure of a particular seedlot. The BCMF has done considerable work on supplemental pollination techniques. However, these techniques are still generally at the prototype or testing stage.

The use of supplemental pollination requires the ability to collect and store large quantities of pollen. Most orchard complexes are developing facilities for the extraction and short-term storage of pollen. The BCMF is developing a pollen bank for long-term storage of pollen at Duncan. Evacuated, vacuum-sealed containers consistently produce better seed yields although Webber (1980) is working on more efficient methods of storing large quantities of pollen.

The work of Owens et al. (1981) will prove invaluable in determining the timing of supplemental pollination in Douglas-fir.

As the orchards are still relatively young, few technical or logistical problems have been encountered in cone harvest. Orchard lifts or orchard ladders are presently used for access to the trees. Cones are placed in 1/3 hl cone sacks and stored on racks in cone sheds before shipment to the extractory.

## CONCLUSION

In conclusion, seed orchard management in British Columbia is in a very exciting time. We are starting to learn to manage Douglas-fir seed orchards with some degree of expertise but the establishment of orchards of six to eight additional species will provide considerable challenge and tax our ingenuity to the fullest.

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[1] Gordon Miller, Entomologist, Canadian Forest Service, PFRC, Victoria

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# RECENT DEVELOPMENTS IN ENHANCEMENT OF SEED PRODUCTION IN CONIFERS

**Stephen D. Ross**

*Research Branch, British Columbia Ministry of Forests,*

*Victoria, B.C.*

and

**Richard P. Pharis**

*Biology Dept., Univ. of Calgary*

*Calgary, Alberta*

## ABSTRACT

Recent developments in techniques to enhance flowering and seed production in conifers are reviewed. Current operation status and future requirements are discussed, and optimum strategies for their use in seed orchards considered. The conventional method of producing "genetically improved" seed in wind-pollinated, soil-based orchards is found wanting. Two new seed orchard concepts - the hedged outside, and indoor potted orchards - both full-sibling, and both offering the potential for earlier seed production and higher genetic gains, are also examined.

## RÉSUMÉ

Les auteurs examinent les progrès récents des techniques d'amélioration de la floraison et de la production de graines chez les conifères. Ils discutent de leurs applications actuelles et futures et considèrent les façons optimales de les utiliser dans les vergers à graines. Selon eux, la méthode classique de production de graines génétiquement améliorées, dans les vergers en pleine terre où la pollinisation est anémophile, est déficiente. Ils examinent deux nouvilles méthodes: les vergers à graines à l'extérieur et entourés de haies ou à l'intérieur et constitués de plants en pots, dans les deux cas de descendance biparentale et offrant la possibilité d'une production plus précoce de graines et d'améliorations génétiques plus considérables.

## INTRODUCTION

Poor flowering in seed orchards remains a major obstacle to the rapid and full realization of tree improvement benefits. Significant progress, however, has and is continuing to be made both in the area of more effective techniques to enhance flowering and cone production, and in new concepts of orchard management. These recent developments, with particular emphasis on current operation status and further research needs, are reviewed herein.

## FLOWERING ENHANCEMENT AND CONE PRODUCTION TECHNIQUES IN CONVENTIONAL ORCHARDS

Within the conventional seed orchards we are confined to basically four techniques: the cultural treatments of nitrogen fertilization, girdling and root-pruning, and the application of hormones, of which gibberellins (GAs) show the most promise. Other treatment/techniques may be feasible in the "new concept seed orchard", but discussion of these will be deferred to later sections.

Properly used in conjunction with other management practices (discussed under Growth Control) these four treatments offer considerable potential for enhancing yields of present-day seed orchards. And, increased effectiveness from all four treatments has resulted from our better understanding of the critical time(s) for influencing flowering (see Owens and Molder 1978). Additionally, we are now aware of the importance of proper siting (e.g. on well-drained soils and in regions of high solar insolation during the conebud differentiation period) for new orchards to ensure earlier and more abundant seed production.

### Cultural Treatments

As Masters (1981) has examined Weyerhaeuser Company's experience with the cultural treatments of girdling and nitrogen fertilization in Douglas-fir orchards, our discussion of them will be brief (see also reviews by Puritch 1972, Jackson and Sweet 1972, Lee 1979). Girdling has generally been the more effective cultural treatment, but for both treatments commercially significant increases in seed production are confined to sexually mature trees on favourable sites, and during years that are very favourable for flowering in the region as a whole. Even so, these treatments have the advantage of being operationally feasible, relatively inexpensive, and can be cost-effective when properly used (Masters 1981).

Puritch (1972) concluded that rootpruning, the third cultural treatment, requires further experimentation before it can be considered an acceptable cone-induction technique in conventional seed orchards. At that time rootpruning had given quite variable results with different species. There was also concern that repeated rootpruning would invite infection and otherwise adversely affect tree health. Since 1972 rootpruning has been successfully used for many years in some southern pine orchards without adverse effects (Gregory and Davey 1977). It has

subsequently been shown in numerous operational and research trials to be one of the most consistently effective flower stimulation treatments for Douglas-fir (Silen 1973, Anon. 1977, Masters 1981, Ebell[1] per. comm.).

In trials on Douglas-fir, 10-fold and greater increases in both female and male flowering were not uncommon, although, as with all treatments, best results were obtained in years that were favourable for cone induction in the region as a whole. Since inadequate pollen production rather than poor female flowering is the major problem in young orchards, it is particularly significant that rootpruning is especially effective for inducing pollen cone-buds on ramets and seedlings that are too young to respond well to other treatments, including GAs.

Based on a review of the mainly unpublished results on rootpruning in Douglas-fir, Ebell (pers. comm.) concluded that rootpruning should be sufficiently severe to cause a 40-60% reduction in height increment for maximum flowering response. Cone abortion and even death of the tree can result if the stress during induction is much higher. Ebell also observed that repeated annual rootpruning depressed accumulated cone yields, whereas biennial treatment consistently resulted in good biennial cone-bud induction. Trees should be well fertilized and irrigated the year following stress treatment, otherwise a two-year wait will be required for the next rootpruning treatment to be effective (Karlsson[2] pers. comm.).

Better methods for rootpruning large trees must still be developed before routine treatment of seed orchards can be considered cost-effective. Commercial tree spades commonly used in the West are, however, suitable for rootpruning small numbers of small trees. Unfortunately, the models required for larger seed-orchard trees are too expensive and too slow for operational use on a large scale. Sub-soiling by means of a tractor-mounted ripping blade, or vibrating plow, has proved to be a quick and effective treatment in loblolly pine orchards (Gregory and Davey 1977), and its use in one Douglas-fir orchard is currently being evaluated by Masters (1981). Additional research is also required to optimize treatment timing (spring vs fall), severity (depth and distance from tree) of initial and re-treatment in relation to tree size and site, and the optimum tree size to begin a regime of biennial rootpruning.

Gibberellins

For many years it appeared that GAs would only promote flowering in members of the Cupressaceae and Taxodiaceae families (see review by Pharis and Kuo 1977). For these species precocious and

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[1] L.F. Ebell, B.C. Ministry of Forests, Victoria, B.C.

[2] S.A.I. Karlsson, B.C. Ministry of Forests, Victoria, B.C.

enhanced flowering could readily be induced, even in very young seedlings by exogenous applications of a number of gibberellins, including the most readily available one, gibberellic acid ($GA_3$). Unfortunately, Pinaceae species were virtually unaffected by $GA_3$. However, in 1973, following leads from bioassay investigation, we (Ross and Pharis 1976) found that certain other GAs, notably the mono-hydroxylated $GA_{4/7}$ mixture (e.g. $GA_4$ and $GA_7$ exist in a less oxidized form than $GA_3$ which has two hydroxyl groups), would promote flowering in Douglas-fir. The efficacy of $GA_{4/7}$ as a cone-induction treatment has now been demonstrated for at least 12 species representing four genera of Pinaceae (see references in Pharis et al. 1980, Ross et al. 1981). Auxins, and to a lesser extent cytokinins, can enhance the efficacy of $GA_{4/7}$ in some species, although neither they nor other plant growth substances are particularly effective by themselves (Ross 1976, Pharis et al. 1980, Tompsett 1978).

Giberellin $A_{4/7}$ has proved to be about the most effective and reliable flowering stimulation treatment for a wide variety of Pinaceae family conifers. Four- to six-fold increases in cone production are routinely achieved, with considerably greater responses not uncommon (see McMullan 1980, Ross et al. 1981). Rootpruning alone has elicited flowering responses of greater magnitude, but to our knowledge only for Douglas-fir (S.C. Cade et al., Weyerhaeuser Co., unpublished results). Although the hormone is most effective on sexually mature trees (see Ross 1976, 1978, Greenwood 1978), the age at which flowering can be induced is being continually reduced as research optimizes treatment conditions. Thus Brix and Portlock (1982) induced precocious flowering in potted western hemlock seedlings that were only two years old from seed by means of $GA_{4/7}$ and water stress treatment — interestingly, this most responsive of all Pinaceae species also has one of the longest juvenile phases, 20-25 years.

Best results are usually achieved when the $GA_{4/7}$ mixture is applied in combintaion with cultural practices, which by themselves may be ineffective in that particular instance. Both nitrate fertilization and girdling are effective in this regard (Ross and Pharis 1976, Ross et al. 1981), but the strongest synergistic effects have occurred with water stress (Ross 1978, Pollard and Portlock 1981). Preliminary indications are that $GA_{4/7}$ plus rootpruning will be especially effective treatment combination, at least for Douglas-fir (Ross unpub.).

At present GAs have their greatest usefulness in inducing early flowering for breeding purposes. As with rootpruning, more cost-effective application methods must be developed before hormonal treatment of large seed orchard trees can be considered practical, except on a limited scale (e.g. in Finland the several-fold increases in seed yield by $GA_{4/7}$ in Scots pine were accomplished at a cost for hormone of about 0.2¢/seed — not very much until one considers that 150 million seedlings are planted each year). Western hemlock and those species of Cupressaceae and Taxodiaceae that flower profusely in response to low-concentrations of aqueous GA foliar sprays are currently exceptions.

But, for most Pinaceae species $GA_{4/7}$ foliar sprays are relatively ineffective -- they are also costly, being quite wasteful of this still relatively expensive hormone ($CDN 12.00/gram, 1981). Unfortunately, the more effective (in terms of hormone cost) stem- and branch-injection methods are laborious and not well suited for large trees (Pharis and Ross 1976). The prospects of developing cost-effective GA foliar sprays are good however. Special anti-evaporant oils and new ultra low volume spray (ULV) techniques have resulted in greatly enhanced biological activity from foliar-applied pesticides at only a fraction of dosage previously required with conventional aqueous sprays (Coffee 1979). Their use with GAs on conifers is currently being assessed in British Columbia. Further research is thus required to determine the best application techniques, the concentration of hormone, and the most effective treatment schedule for each species.

Growth Control

How long until an orchard comes into commercial cone production appears to be a function of tree or propagule size, not age. Hence, the faster the early growth rate, the better. This is why seedling orchards become more productive sooner than clonal orchards, despite propagation of clonal orchards from already sexually mature individuals (Puritch et al. 1979). Seedlings characteristically grow much faster than vegetative propagules and they also have more branches (potential flowering sites) per unit of stem (Copes 1976). While it is true that poor flowering is normally associated with good growing sites, this is because the stress conditions required for enhanced cone-bud induction seldom occur at the proper time. However, it now appears that we "can have our cake and eat it too" through use of growth-acceleration techniques.

Although long known for woody angiosperms (Jackson and Sweet 1972), it has only recently been shown that subjecting conifer seedlings during their first year of free growth to extended photoperiods within the greenhouse can greatly hasten the onset of flowering following outplanting (Young and Hanover 1976, Cecich 1981).

This method of growth acceleration is much less effective on vegetative propagules where the pattern of slow and determined growth is already established. However, on mature scions growth rate can be maximized by using robust scion material and field grafting onto vigorous, well established seedling rootstock (Copes 1980). Although pot grafting has advantages from the standpoint of convenience, Copes (1980) has shown that their performance following outplanting is decidedly inferior, even in the absence of apparent pot-binding. Rooted cuttings require even more time to attain cone-production size (Copes 1976), and this method of orchard establishment can only be recommended for those species where rootstock-scion incompatibility makes the use of grafts too risky. Whatever the method of propagation, the importance of weeding, irrigation, fertilization and stocking control to minimize the time required for orchard trees to attain an optimal cone-production size cannot be over-emphasized.

Seed orchard managers are often reluctant to accelerate growth since the trees will all too rapidly become too tall for economical cone harvesting and other management practices. Also, the view still prevails that height control in conifer seed orchards is neither practical nor effective. One method of overcoming this problem, annual leader removal (frequently also competing branches) beginning at a relatively young age (6-10 years) usually depressed seed yields, often for several years after pruning was discontinued (Copes 1973, Long et al. 1974). Furthermore, the check to height growth was only temporary, with vigorous upper-crown branches rapidly replacing the removed terminal once apical dominance had been interrupted.

The main reason why this method of height control has been generally detrimental appears to be that pruning was initiated before the tree crown had sufficiently developed. Working with radiata pine in Australia, Matheson and Willcocks (1976) found that a late, very severe top-pruning (pollarding) not only gave effective height control (3-5 years), but actually increased cone production. Flowering after pollarding of 22 m ramets to 8 m was increased greater than 70% over the next two years. Similar results were achieved by Heinstaedt (1981) in a 15-year-old grafted white spruce orchard by top-pruning the upper 33% of live crown. Pollarding of a Douglas-fir orchard has also given encouraging results in a preliminary trial by Master (1981). These studies only begin to indicate the potential that crown management offers for increasing the proportion of cone-producing branches. Research aimed at determining the optimum tree size to begin treatment and the method and severity of pruning, should be given the highest priority, with special concern toward making the application of the $GA_{4/7}$ hormone treatment more effective.

## TREATMENT STRATEGIES

The question of optimum treatment strategy has recieved little research attention. However, there are some general guidelines, and we can indicate areas where further research in techniques is urgently needed in order to realize maximum cone-induction benefits.

1. Treatments should be tailored for specific purposes. Thus, although neither GAs nor rootpruning has yet attained an operational, cost-effective status, their selective use to enhance seed production by the "genetically best" clones may be justified. Also, certain treatments (e.g. girdling/root-pruning) have a tendency to preferentially promote male flowering, and should be used for those clones or orchards where seed yields or genetic quality is being limited by inadequate pollen production.

2. The optimum treatment(s) will vary with the site (and with annual climatic conditions, but these can only be predicted "on the average"). Nitrate fertilization will not be particularly effective on sites where, during cone-bud differentiation, a high soil pH and cool, moist soil conditions favour its rapid reduction (Ebell 1972). Rootpruning may be absolutely essential on wet sites, with or without

GA4/7 treatment, if any flowering at all is to be realized. But, rootpruning could depress yields if used on an already stressful site. Unfortunately, we do not yet know how the various treatments influence flowering, and hence how they should be used to compensate for different limitations of site.

3. The optimum treatment(s) changes with age. This is another area where further research is urgently required, although in general we know that the older the tree, the less the stimulus needed. There is also some evidence that the severe stress necessary to induce flowering in young trees can depress cone and seed yields in older trees (Ross 1978).

4. There is an optimum tree size for initiation of treatments that stimualte maximum flowering per propagule. Most orchards are designed to concentrate seed production on a relatively few large trees, and crown development (and thus future yields) can be severely depressed if stress conditions are initiated too soon. Growth-acceleration techniques should be used to attain this optimum size (which remains to be determined experimentally) as rapidly as possible.

5. Biennial treatment--half the orchard one year the other half the next in an alternating manner--will result in greater accumulative seed yields than annual re-treatment of the entire orchard. Firstly, the trees will require at least a year to physically recover from rootpruning (or girdling) for re-treatment to be very effective. Secondly, the stress conditions conducive to cone-bud differentiation may result in increased cone and seed abortion. And thirdly, good growing conditions during the off-treatment year appear to be required for shoot recovery, and for the production of vigorous terminal buds having a high potential for differentiating cone-buds.

## NEW SEED ORCHARD CONCEPTS

Despite recent hormonal and cultural treatment developments in cone-bud enhancement and height control techniques, the traditional wind-pollinated seed orchard remains a slow, unreliable and generally inefficient method for production of genetically improved seed. Control over (or amelioration of) unfavourable environmental conditions will always be limited, and all the management problems associated with large trees can only be reduced, not eliminated.

Further, the lack of control over pollen parentage results in genetic gains considerably below those possible with contolled pollination. Two new seed orchard concepts have recently be proposed which we believe are deserving of serious consideration and further research. These are (1) the hedged, full-sibling orchard (Sweet and Krugman 1978) and (2) the indoor potted orchard (Haeussler and Ross 1981).

Hedged, Full-Sibling Orchards

Sweet and Krugman (1978) describe a new approach to the production of full-sibling seed, which although specifically aimed at radiata pine, could be adapted to any species. What they propose is in essence a group of 2-clone orchards where ramets are grown in clonal "hedges" kept low by pruning, and in which pollen parentage is controlled through artificial pollination rather than by juxtaposition of clones. In addition to making artificial pollination practical, the low height of ramets (2-4 m) greatly facilitates many treatments that promote flowering, as well as the protection and harvesting of cones. The clonal-row design enables treatments to be custom tailored and optimally timed to the requirements and phenology of individual clones. It also makes for more efficient use of valuable orchard land. Inferior clones can be replaced with new selections, while retaining those of maintained genetic superiority, in what we call an in situ advancing-front design. This is possible because the hedged ramets in one clonal row are never allowed to reach a size where they will seriously affect flowering of ramets in adjacent rows.

The hedged orchard is managed for early and sustained high seed yields. Because production is diffused among many small ramets, rather than concentrated on a few large trees, as in conventional orchards, treatments to enhance flowering can be initiated much earlier. The method of crown training also differs substantially from the pollarding treatment previously described. It begins early and, in the case of radiata pine, is intended to favour the abundant production of vigorous shoots for seed cones and/or suppressed shoots for pollen production, to the exclusion of intermediate-vigor shoots which have low potential for differentiating cone-buds of either sex. For other conifer species it remains necessary to better characterize the types of shoots with high "sexual differentiation potential", than to develop the pruning techniques to promote their rapid production of small ramets.

Radiata pine breeding arboreta have been managed along lines similar to the hedged orchard concept for a number of years in New Zealand and Australia. Although seed yields per hectare have not been compared in relation to conventional orchards, they are expected to be higher. Crown training will enhance the potential for flowering, and cone enhancement techniques should also be more efficient (and effective) on the smaller ramets. Because trees are much smaller, one's ability to protect the developing cones and seeds is greater, and seed set can be icreased through artificial pollination which, in pine at least, will also reduce conelet abortion.

Much of the basic technology for artificial pollination exists now. The challenge will be to develop cost-effective methods for harvesting, processing and storing, and applying the large quantities of pollen required for high volume production of full-sibling seed. To facilitate pollen management we envisage the creation of separate orchards managed specificially for seed or pollen production. The female orchard should, so far as possible, be geographically isolated from

sources of foreign pollen, although overhead sprinklers can be used to delay female receptivity and thus avoid serious contamination (Fashler and Devitt 1980). Pollen storage techniques have improved considerably in recent years, but fresh pollen is still preferred. Therefore, it will be desirable if the pollen orchard can be situated where pollen shed will predictably occur several weeks before seed cone receptivity, so as to allow sufficient time for pollen harvesting and processing. Part of the challenge must also rest with tree breeders to identify and develop parents that are not only genetically superior, but also have a high degree of male/female compatibility in pollination/fertilization if we are to justify the extra cost of producing full sibling progeny.

Indoor, Potted Orchards

The idea of culturing ramets indoors in pots to accelerate flowering for breeding purposes is not new (Pharis and Ross 1976, Greenwood et al. 1979), and we (Haeussler and Ross 1981) and others (Luukkanen 1980, Rottink[1] pers. comm.) are currently exploring its application for volume seed production.

The indoor, potted orchard has many advantages over soil-based orchards. Most important is the ability to reliably and precisely provide optimal environmental conditions for hastening the age at which cone-buds can be repeatedly induced, and cones matured, in large numbers per propagule, both over a sustained period of time. These conditions are seldom achieved simultaneously in nature, even on the best flowering sites. Potted stock is not tolerant of mismanagement, and the problems of high mortality of trees, cone-buds, and cones, together with poor seed set, that have been associated with container orchards are directly related to our ignorance of and/or lack of attention to proper horticultural practices.

Many studies have demonstrated the early and enhanced flowering of potted stock subjected indoors to inductive water stress and high temperatures at the appropriate time (Chalupka and Giertych 1977, Tompsett and Fletcher 1977, Luukkanen 1980, Ross, unpub.). The efficacy of $GA_{4/7}$ and other induction treatments is also greatly enhanced (Ross 1978, Greenwood et al. 1979, Pollard and Portlock 1981, Brix and Portlock 1982). Additionally, there are other potentially highly effective induction treatments, such as out-of-phase dormancy (Greenwood 1981) and heat stress (Pollard and Portlock 1981), that can only be used on indoor, potted orchards.

There are also obvious advantages of working indoors with small potted propagules: ease of treatment application, pollination and cone harvesting; increased efficiency as a result of better working conditions; and relative freedom from foreign pollen. The fact that trees can be moved with minimal expense makes for efficient space

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[1] B. Rottink, Crown Zellerbach, Wilsonville, Oregon.

utilization, as well as easy roguing and introduction of new clones. The ability to separate trees for special treatment is a particularly important consideration with respect to pollen management e.g. for forcing early pollen shed and delaying female receptivity.

Currently, high production cost appears to be the major disadvantage of indoor, potted orchards. However, increased seed yields and more efficient management techniques should reduce this cost (per superior seed) considerably. And, the technology of managing trees in pots for large-scale seed production is still relatively new and unproven, and management techniques must be made more cost-effective. There is also the question of how long orchard trees can be profitably maintained in pots. From the experience of commercial nurseries, 10-15 years with improved crown and root management does not seem unreasonable. By this age new, improved parental selections will be available for replacement, and the older trees could be outplanted to provide an immediately productive hedged or conventional orchard if regeneration needs could not be met from the potted seed production orchard of full sibling.

Western hemlock (see Haeussler and Ross 1981) and species of Cupressaceae and Taxodiaceae which are known to flower profusely in response to GA and/or water stress treatments are ideal candidates for the indoor, potted orchard. So too are those highly recalcitrant species (or provenances) for which a consistent seed supply is urgently required. The ability to rapidly respond to changing seed requirements also makes the indoor, potted orchard a highly suitable production method for so-called "minor species" whose potential value has yet to be determined. And, even for species that flower moderately well in the traditional seed orchard, there are the prospects for earlier seed production from desirable individuals, hence higher genetic gains. Further, in many areas prime seed orchard sites are becoming scarce and quite expensive. Potted orchards require only a fraction of the space of traditional orchards and they can be located on inexpensive and otherwise non-productive land.

It is axiomatic that progress in tree breeding remains little more than an academic exercise until the genetic gains are actually realized in better, faster growing forests. The two new orchard concepts discussed here are ways to ensure that these benefits are rapidly and fully realized. Others, such as clonal propagation through adventitious budding (via tissue culture) or rooting of needle fascicles (see Rauter and Hood 1981) may, in the future, offer the potential of multiplying each genetically superior seed into at least several hundred propagules. If so, then the potted orchard concept will become even more attractive.

Finally, despite its inherent limitations, the conventional wind-pollinated orchard, if it must be used, can become a more cost-effective production method if the recent developments (and future improvements) in cone production enhancement techniques are implemented.

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# POLLEN MANAGEMENT THROUGH PHENOLOGICAL CONTROL OF DEVELOPMENT

John N. Owens

*Biology Department*

*University of Victoria*

*Victoria, British Columbia*

## ABSTRACT

The general sequence of pollen cone and pollen development are described in 13 conifers native to British Columbia in relation to: (1) the time of winter dormancy; (2) the sequence of cell division in pollen development; and (3) the phenology of post-dormancy pollen cone and pollen development. The potential for altering the phenology of pollen cone and pollen development within a seed orchard is discussed in relation to the stages of development most likely to respond to cultural treatments.

## RÉSUMÉ

On décrit le processus général de développement des cônes de pollen et du pollen pour 13 conifères indigènes de la Colombie-Britannique aux points de vue suivants: la durée de la dormance hivernale, le processus de division cellulaire durant le développement du pollen et la phénologie du développement des cônes de pollen et du pollen après la dormance. On discute des possibilités de modifier la phénologie de ces développements dans un verger à graines en essayant de déterminer à quels stades du développement les traitements culturaux seraient le plus efficaces.

## INTRODUCTION

In seed orchards we must have viable pollen available when it is needed for pollinations. This requires the careful management of the pollen-cone crop. To do this we must understand the phenology of both pollen-cone and pollen development for each conifer species. From the outset we must realize that there are limitations in our ability to manipulate the phenology of pollen cone development. The duration of only certain stages of development can be altered significantly and in a seed orchard it is presently feasible only to increaase the duration of these stages by cooling

The function of pollen is to provide a means for the transfer from the male cone to the female cone of the cell which forms the male gametes. We are aware of the many morphological differences between pollen of different conifers (Foster and Gifford 1972, Singh 1978).

However, little is known about the phenology of pollen development for species growing in their native habitat and even less is known about the effects on phenology when we move a species into a seed orchard outside its natural range.

In this paper I would like to describe the general sequence of pollen cone development which occurs over two growing seasons and show the variation which occurs in: (1) the time of winter dormancy: (2) the sequence of cell division in pollen development; and (3) the phenology of post-dormancy pollen cone and pollen development in 13 native conifers. This should provide some insight into the potential for phenological control of pollen-cone and pollen development and the stages of development most likely to respond to cultural treatments.

## THE TIME OF WINTER DORMANCY

Pollen cones are initiated during the late spring or summer of the year before these cones shed their pollen (Owens and Molder 1978). All microsporophylls are initiated before winter dormancy but the stage of microsporangial development reached varies between species. Pollen cones of different species may become dormant, as measured by the absence of cell divisions: (1) soon after sporogenous tissue develops: (2) after pollen mother cells differentiate from the sporogenous tissue; (3) during meiotic prophase of the pollen mother cells; or, (4) after the pollen develops (Fig. 1).

Whether winter dormancy occurs at the sporogenous tissue stage as in Pinus (Kupila-Ahvenniemi et al. 1978, Owens and Molder 1977, 1981) or at the pre-meiotic pollen mother cell stage as in Abies and Picea (Owens and Molder 1977, 1979, 1980a; Singh and Owens 1981a, b) may make little difference to the ultimate pollen development. In these genera both meiosis and pollen development occur after winter dormancy. Ultrastructural studies of overwintering sporogenous cells of Pinus have shown that a true dormant period does not occur, rather nuclear and cytoplasmic changes occur in sporogenous cells throughout winter dormancy and this period is more correctly called a period of reduced activity rather than dormancy (Kupila-Ahvenniemi et al. 1978). Similar studies have not been made for Abies and Picea.

In Larix, Pseudotsuga, Thuja and Tsuga, meiosis begins in the fall then becomes arrested when pollen mother cells reach either the pachytene or the diffuse (diplotene) stages of meiosis (Owens and Molder 1971b). After dormancy, meiosis is rapidly completed followed by pollen development. As in Pinus, many changes occur in the pollen mother cells during winter dormancy. In Pseudotsuga chromosomes change from diffuse to granular, the nuclear membrane becomes more distinct and there is a great increase in the number of cytoplasmic organelles.

In Larix growing in Sweden, when pollen mother cells were induced to develop beyond the diffuse stage before winter dormancy, there occurred a higher incidence of pollen abnormalities than in trees in which pollen mother cells overwintered at the diffuse stage (Eriksson

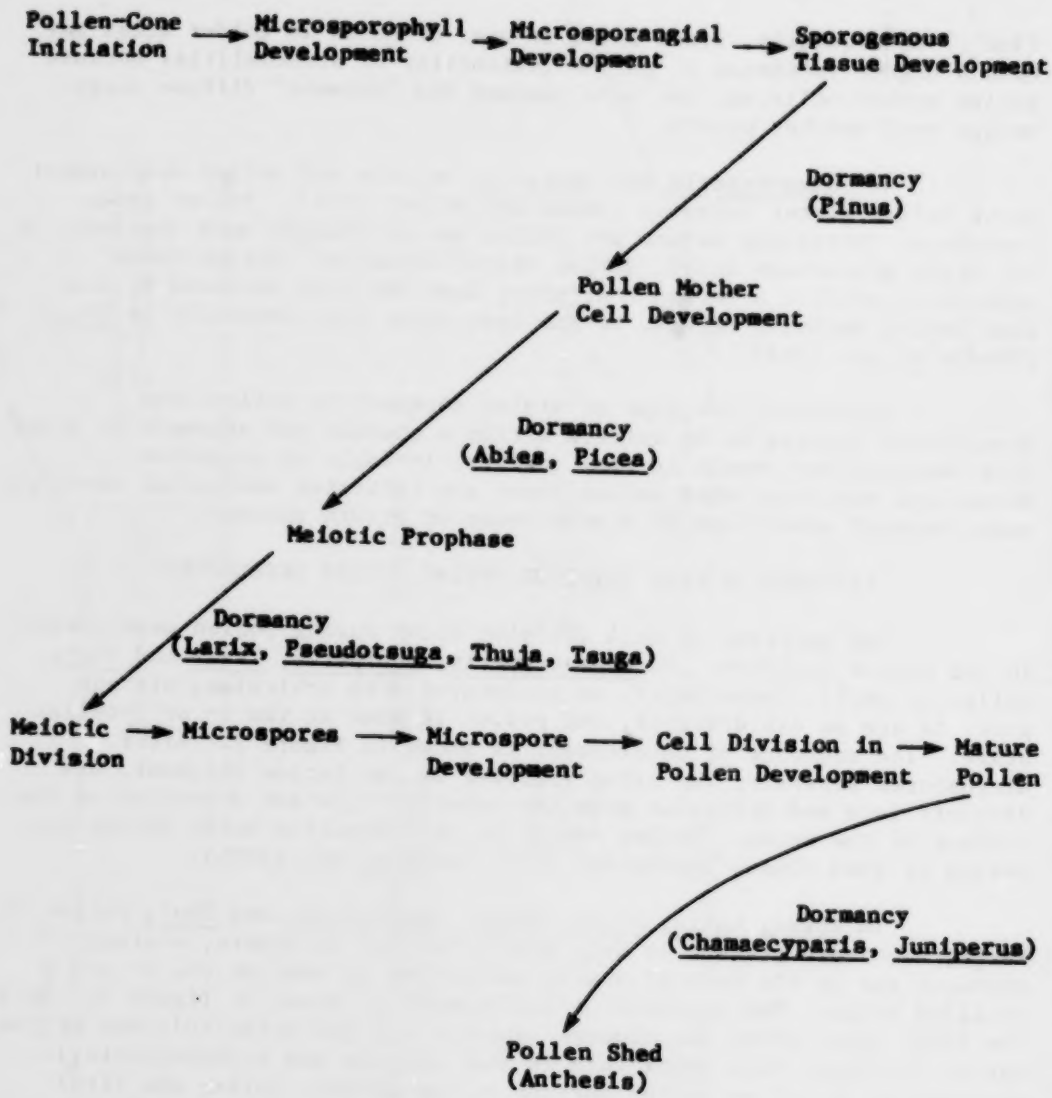


Fig. 1 Stages of pollen cone and pollen development and the times when dormancy may occur in different species.

1968). Consequently, trees moved to seed orchards in colder areas may have a higher incidence of pollen inviability or abnormalities because pollen mother cells may not have reached the "dormant" diffuse stage before cold weather occurs.

In Chamaecyparis and Juniperus meiosis and pollen development occur before winter dormancy (Owens and Molder 1974). Pollen cones overwinter containing mature dry pollen and no changes were observed, at the light microscope level, during winter dormancy. Pollen cones apparently require a sequence of short days and cold followed by long days before anthesis occurs, as has been shown experimentally in Thuja (Pharis et al. 1969).

Therefore, the time of winter dormancy in pollen cone development appears to be uniform within a species and attempts to alter this sequence may result in poor quality, inviable or no pollen. Exceptions may occur when pollen cones are initiated and pollen develops under unusual conditions in a greenhouse or growth chamber.

## PATTERNS OF CELL DIVISION DURING POLLEN DEVELOPMENT

Two patterns of cell division occur during pollen development in our native conifers. In Chamaecyparis, Juniperus, Taxus and Thuja, pollen is small, lacks sacci, is sculptured with orbicules, storage products are as oil droplets, and pollen is shed at the 1- or 2-celled stage. The sequence of development is shown in Figure 2. After microspores separate, the exine followed by the intine thickens, oil droplets form and orbicules from the tapetal cells are deposited on the surface of the exine. Either one or no cell division occur before the pollen is shed (Owens and Molder 1974, Owens et al. 1980b).

In Abies, Larix, Picea, Pinus, Pseudotsuga and Thuja pollen is large, sacci are present in some genera but not in others, storage products are in the form of starch and pollen is shed at the 4- or 5-celled stage. The sequence of development is shown in figure 3. As in the first type, after microspores separate and the exine followed by the intine thickens, then sacci form in some species and a characteristic sculpturing may occur on the surface of the exine. Unlike the first type, either three or four cell divisions occur before the pollen is shed (Owens and Molder 1971, 1975, 1977, 1979a, b, 1980a, 1981; Singh and Owens 1981a, b).

The sequence of cell divisions normally occurs just before the pollen is shed. In both types two non-motile male gametes form after the pollen reaches the seed cone and germinates. Variations may occur in the normal sequence of cell divisions but the frequency is usually not high and normally results in small amounts of inviable pollen.

## PHENOLOGY OF POST-DORMANCY POLLEN CONE DEVELOPMENT

The phenology of past-dormancy pollen cone development has been studied in 13 of our conifer species (Fig. 4). Within a pollen cone,

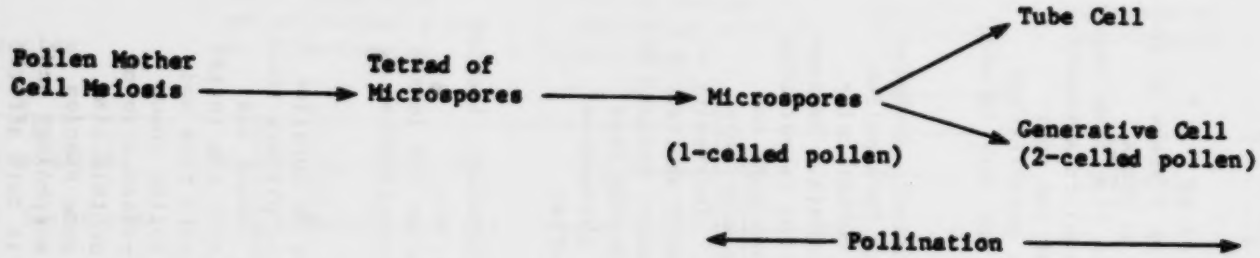


Fig. 2 Pollen development in Chamaecyparis, Juniperus, Taxus and Thuja. Pollen is shed at the 1- or 2-celled stage.

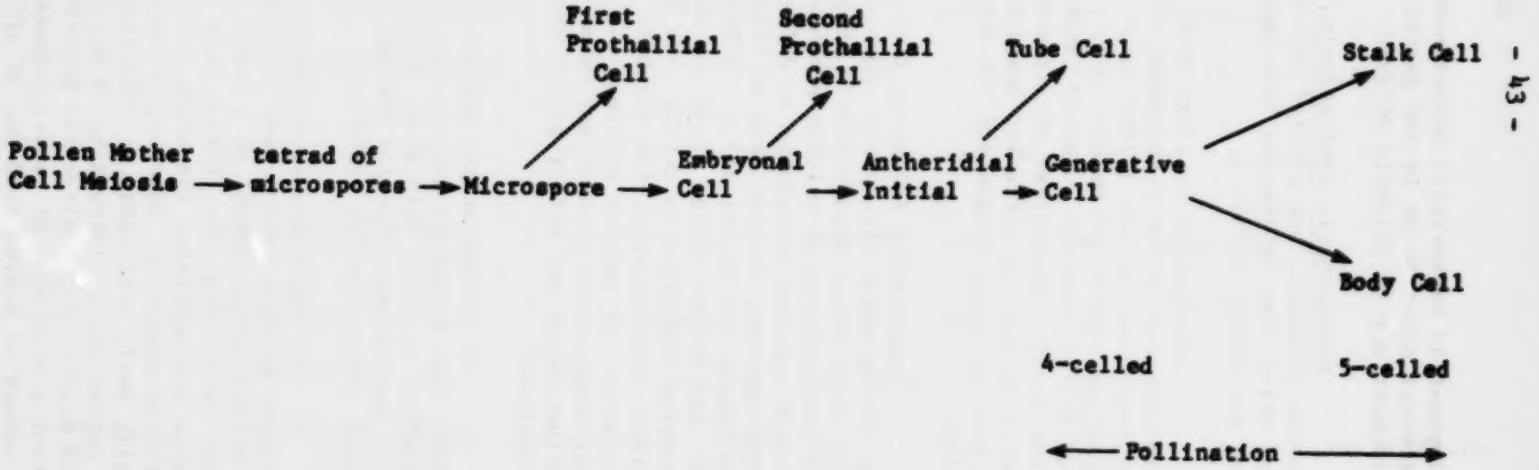


Fig. 3 Pollen development in Abies, Larix, Picea, Pinus, Pseudotsuga and Tsuga. Pollen is shed at the 4- or 5-celled stage.

development is essentially synchronous in all pollen sacs and if differences occur it is in the distal pollen sacs of a cone where development may be slightly delayed.

Chamaecyparis nootkatensis, which forms pollen before dormancy, as do the junipers, has a brief post-dormancy stage of only 1 to 2 weeks during which time no changes have been observed in the pollen (Fig. 4) (Owens and Molder 1974).

Other native conifers have a post-dormancy period of pollen-cone and pollen development which may be as short as 5 weeks as in Larix (Owens and Molder 1979b) to as long as 12 weeks as in Tsuga mertensiana (Owens and Molder 1975) (Fig. 4). This is the time from the end of pollen-cone-bud dormancy (when cell divisions resume) to anthesis (pollen shed). Regardless of differences in the length of the post-dormancy period, in different species, their pollen cones pass through five post-dormancy stages and the duration of each stage may vary between species.

Immediately following dormancy there is a pre-meiotic division stage during which either the sporogeneous cells divide to form pollen mother cells which enter meiotic prophase, or the pollen mother cells, which overwintered in meiotic prophase, rapidly resume meiosis. Because different species overwinter at different stages this period is variable between species, ranging from as little as 1 week in Pseudotsuga and Larix (Owens and Molder 1971a, 1979b) to 4 weeks in Pinus monticola (Owens and Molder 1977a, Singh and Owens 1981a) (Fig. 4). Increasing or decreasing temperatures during this time could significantly shorten or lengthen, respectively, the duration of this stage. However, because DNA replication, chromosome pairing, etc., may be occurring during this stage, temperature changes may cause deleterious gene or chromosomal mutations which may affect pollen development or appear after pollination.

The second stage, meiotic division, is uniformly short, lasting no more than 1 week in any species studied thus far (Fig. 4). Attempting to alter this stage would not significantly alter the length of the post-dormancy period and may result in meiotic irregularities causing reduced pollen viability.

The third stage, microspore development, varies in duration in different species from 1 week in Pinus monticola and Thuja plicata (Owens and Molder 1977a, 1980b) to 6 weeks in Tsuga mertensiana (Owens and Molder 1975) (Fig. 4). During this stage microspores within the tetrad enlarge and separate, the exine thickens, sacci (if present) form and starch accumulates. However, no cell divisions occur. Pollen cones usually swell noticeably at this time because of the increased size of the pollen sacs. Increasing or decreasing temperatures at this time could significantly alter the duration of this stage in some species without a high risk of genetic damage. However, pollen morphology and the amount of stored food may be affected and these may in turn affect pollen viability, germinability and vigor.

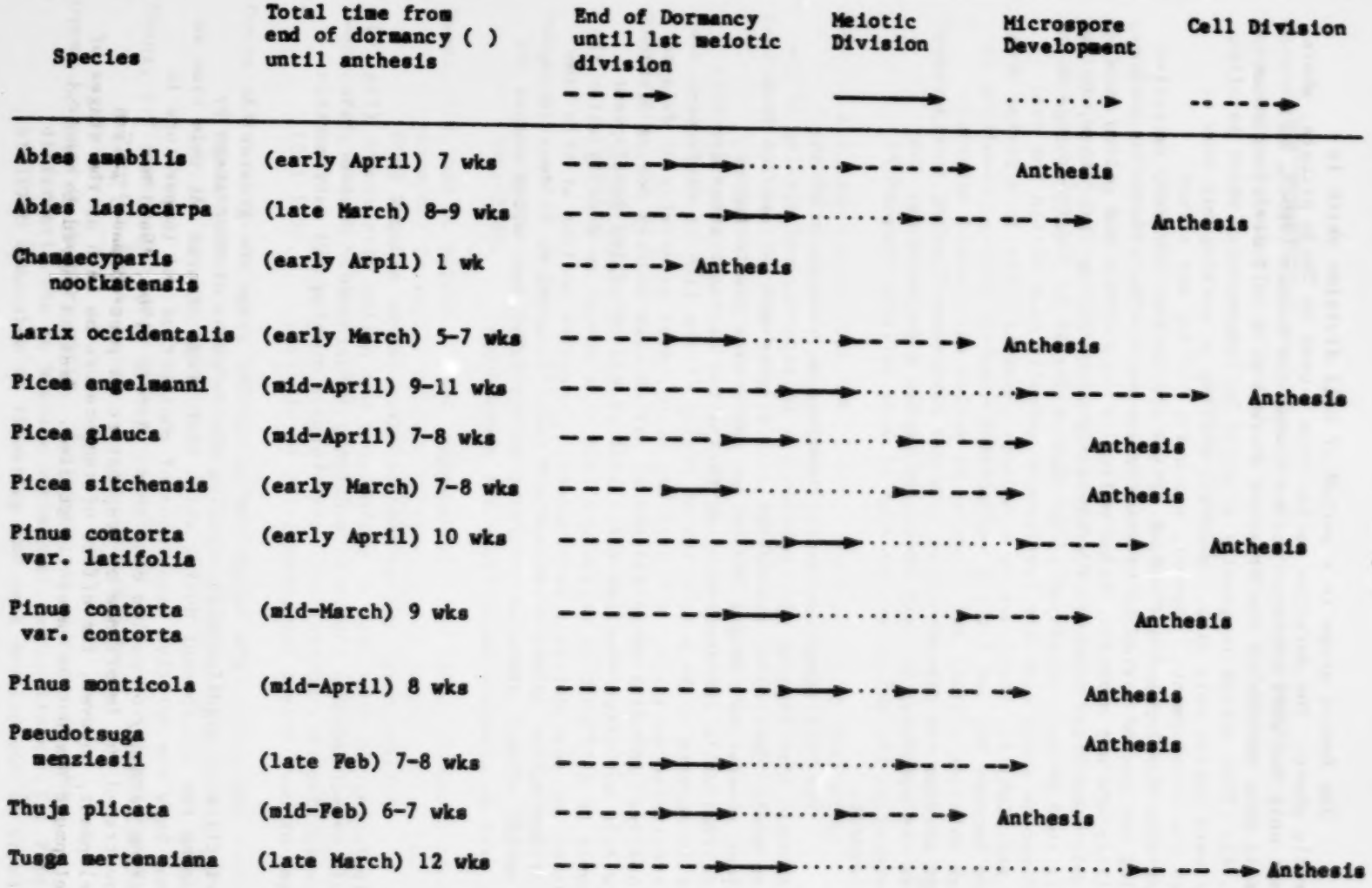


Fig. 4 Phenology of post-dormancy pollen cone development in 13 native conifers.

The fourth stage is a period of cell division which is generally short. The duration varies from 1 week in Thuja plicata, where at most only one cell division occurs (Owens and Molder 1980b), to 3 weeks in some members of the Pinaceae where 3 to 4 cell divisions occur (Fig. 4). This period is greatly affected by temperature, which is often quite warm during this time. Moderate cooling or warming may slow or hasten the development. However, excessive cooling may arrest pollen-cone development and reduce pollen production, whereas, excessive warming may caused pollen to be shed prematurely. The effects on pollen viability are not certain. Since pollen is free within the pollen sacs and only some final touches of sculpturing occur during this stage, it is likely that pollen, if forced to be shed at the 2- or 3-celled stage in the Pinaceae would complete development normally once within the seed cone and viability would not be affected. However, this is a period when pollen becomes dry and forcing may prevent complete drying, resulting in a high moisture content and clumping of pollen which would adversely affect storage and dissemination. In the laboratory forcing at this time upsets the synchrony of cell divisions within a pollen cone. Consequently, the pollen may be shed at more variable stages of development.

The last stage, anthesis, involves an elongation of the pollen-cone axis causing microsporophylls to separate and opening of the pollen sacs. Opening of the pollen sacs in most species results from physical separation along a line(s) of dehiscence consisting of specialized cells differentiated in the pollen sac wall after dormancy. Anthesis appears to be a function of drying if the line of dehiscence has differentiated normally. Anthesis may be hastened by warming or delayed by cooling. Anthesis of an individual pollen cone usually occurs within a few days and often overlaps with later stages of pollen development. It would be difficult to manipulate this time enough to greatly alter the duration of post-dormancy development. Excessive cooling at this time may affect pollen moisture content and cause clumping as it does during the period of cell division. Forcing in the laboratory often causes the cone axis to elongate excessively and prematurely.

## SUMMARY

Pollen production in seed orchards can be managed by manipulating the phenology of pollen-cone and pollen development (Fig. 4) within as yet unknown limits by modifying temperature. However, the potential for this control will vary between species and only certain stages of development can potentially be altered.

Generally, the longer the particular stage the greater the possibility of significantly altering the duration of that stage by changing the environment during which that stage occurs. At this time we do not know the relative importance of photoperiod and temperature in breaking dormancy of pollen cone buds. Sarvas (1962, 1965) has demonstrated the importance of temperature on post-dormancy pollen development, however, the effect of temperature on each of the stages of development has not be carefully studied. Caution should be used to

ensure that phenological manipulations do not cause genetic or morphological damage to pollen which might affect viability.

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# STRATEGIES FOR CONTROL OF INSECT PESTS IN SEED ORCHARDS

Gordon E. Miller

*Canadian Forestry Service*

*Pacific Forest Research Centre*

*Victoria, B.C.*

## ABSTRACT

Seed orchard trees are susceptible to attack by the same complex of insects as nearby forest stands of the same or similar species. Culture practices, such as orchard site selection and cone harvest, can have pronounced effects on the levels of damage done by insects in seed orchards and on the strategies used in insect pest control. Insecticides are currently the only practical agents for insect pest control in seed orchards where need for control is immediate. In Canada, only one insecticide (dimethoate) is registered for use against cone and seed insects (excluding defoliators) and then only on one host (Douglas-fir). An expanded arsenal of insecticides is needed for use in seed orchards. The decision to apply a method of pest control must be based on the value of seed, crop size, expected losses and effectiveness of the control method. This decision requires that techniques for measuring crop size and for predicting seed losses to insects are available.

Strategies for applying insecticides are functions of the insects causing concern, which insecticides are registered for use against those insects, when applications can be made, how the insecticide is formulated, and orchard location. Insecticides should be used only when necessary and in such a way as to maximize the benefit/cost ratio of the treatment. Advantages and disadvantages of contact and systemic insecticides are discussed in relation to seed orchards, as are different methods of application.

## RÉSUMÉ

Les arbres des vergers à graines peuvent être attaqués par les mêmes insectes qui ravagent les peuplements d'espèces identiques ou semblables dans les forêts avoisinantes. Les méthodes de culture, comme le choix des stations et la récolte des cônes, peuvent avior une grande influence sur l'étendue des dégâts des insectes et les stratégies mises en oeuvre pour les combattre. Actuellement les insecticides constituent le seul moyen pratique de répression immédiate des insectes nuisibles. Au Canada, le seul insecticide homologué qu'on peut employer contre les insects (à l'exclusion des défoliateurs) des cônes et des graines c'est le diméthoate, et encore n'est-il efficace que chez le Douglas taxifolié. Il faudrait tout un arsenal d'insecticides pour les vergers. Avant

d'avoir recours à une méthode de lutte contre les insectes, il faut prendre en considération la valeur des graines, l'abondance de la récolte, les pertes prévues et l'efficacité de la méthode; il faut aussi s'assurer de pouvoir disposer de techniques permettant de mesurer la récolte et de prévoir les pertes de semences dues aux insects.

Le choix de la stratégie de lutte à l'aide d'insecticides dépend des insectes en cause, de l'existence d'insecticides homologués contre ces insectes, de la période pendant laquell on peut en faire l'application, de la préparation insecticide à utiliser et de l'emplacement du verger. On devrait utiliser les insecticides seulement lorsqu'ils sont nécessaires et de façon à rentabiliser au maximum le traitement.

On discute des avantages et des inconvénients des insecticides de contact et systémiques relativement aux vergers à graines ainsi que des différentes méthodes d'application.

## INTRODUCTION

Seed orchard trees are susceptible to the same complex of insect pests as nearby stands of the same species. Orchards have characteristics that make them more suitable than forest stands for control of insect pests, namely: 1) establishment costs and crop values are high, 2) constant and close surveillance is possible and remedial actions can be taken quickly, 3) small areas are involved and there is easy access to each tree, and 4) a trained staff is available for diagnosis and treatment of problems (Dinus and Yates 1975).

Each orchard is subject to its own particular complex of insect pests, the complex being a function of the tree species and the location of the orchard. Choice of orchard location is an important consideration, since risk of attack by insects can be minimized or avoided with good orchard location. Orchards should be located on sites suited to good seed production and, if possible, isolated from stands of the same species or closely related species. The prevalence of potentially damaging insects and the probability of damage should be weighed against other factors. Insects of particular interest include cone and seed insects, defoliators and twig and shoot insects.

The importance of cone and seed insects varies among hosts. In B.C., hosts can be categorized by potential losses to cone and seed insects as follows:

| Severe | Sporadic | Minor |
|---|---|---|
| Douglas-fir | Sitka spruce | hemlock |
| interior spruces | western white pine | larch |
| true firs | western red cedar | lodgepole pine |
| ponderosa pine | | |

Trees heavily attacked in forest stands will also be heavily attacked in

orchards, unless the orchards are isolated. The proportions of seed crops destroyed in orchards can vary dramatically from year to year and from site to site. Losses in Douglas-fir orchards in British Columbia have ranged from less that 10% to more the 90%. Cone and seed insects are rated as a top priority problem in producing Douglas-fir seed orchards in B.C. and in producing pine seed orchards in the southern United States (Overgaard et al. 1975).

Seed orchards present a different situation to cone and seed insects than do forest stands. Orchard trees are spaced to promote maximum cone production, a situation that also promotes infestations of these insects (Schenk and Goyer 1967; Kraft 1968; Mattson 1976). Stabilizing and increasing cone production in orchards may also promote increased insect populations (Mattson 1971, 1976). Cone crops are harvested whenever they occur in seed orchards, whereas in forest stands, only heavy and moderate cone crops are harvested and then only when seed from that particular forest site is needed. Most cone and seed insects remain in the cones until after harvest and are removed from orchards with each crop. Thus, these insects cannot overwinter on-site, and must migrate into orchards from adjacent stands to attack crops. A notable exception is the spiral spruce-cone borer, which leaves the cones prior to harvest.

Defoliators, such as spruce budworm and western spruce budworm, can affect seed production by attacking cones directly and through the effects of defoliation. These insects have been important seed destroyers in forest stands during outbreaks (Dewey 1970; Powell 1973; Schooley 1978). Some species of twig and shoot borers are important because they attack conelets as well as shoots (Yates and Ebel 1972).

## STRATEGIES FOR CONTROL OF INSECT PESTS

Strategies for controlling insect pests in seed orchards depend on the insect causing concern, its life history, habits and population dynamics, the tree species involved, the location of the orchard, and methods of pest control available for use. Developing a strategy for a particular situation consists of making a series of decisions.

### Is pest control necessary?

Decisions to apply pest control actions must be based on value of the seed, crop size, expected losses and effectiveness of control actions. The benefit/cost ratio must be great enough (at least 1) to economically justify taking a particular control action (DeBarr 1971; Yates 1977).

Crop inventory is an important factor in determining whether or not control actions should be taken because it is important to know the size of the crop to be protected. Thus, it is important to have a technique available for estimating the number of cones to be expected at harvest. Life tables are particularly useful in crop inventories because they project expected harvests from counts taken early in the development

of cones and they point out key sources of seed loss. Life tables have been developed for cone crops of several species of pines (Shearer and Schmidt 1971: Ebel and Yates 1974: DeBarr and Barber 1975; Mattson 1978; Yates and Ebel 1978).

Insect pest populations should be monitored to determine the need for control actions. Monitoring must be done early enough for such actions to be taken, if necessary, before damage occurs. Two approaches are being developed for monitoring cone and seed insects; namely, egg sampling and adult trapping. The disadvantages of egg counts are that they are tedious and destructive (i.e., cones are removed). Adult trapping avoids both of these problems. Adult trap catches must be related to damage for this technique to be of use. Lights, sex pheromones and host attractants are potential lures for trapping. Light traps have been used to monitor lepidopterans in pine seed orchards in the southern U.S. (Yates 1973; Yates and Ebel 1975). Sex pheromones can be used to monitor population levels of codling moth in fruit orchards (Madsen et al. 1974; Riedl and Croft 1974; Madsen et al. 1975; Vakenti and Madsen 1976) and similar systems could be developed for use in seed orchards. Pheromones are involved in the mating behaviours of many cone and seed insects, including Dioryctria coneworms (Fatzinger and Asher 1971; DeBarr and Berisford 1981; Hanula et al. 1981), Douglas-fir cone moth (Hedlin and Ruth 1968; Weatherston et al. 1977), Douglas-fir cone gall midge (Miller and Borden 1981), spruce seedworm (Weatherston et al. 1977), and ponderosa pine cone beetle (Kinzer et al. 1972). The presence of attractants produced by the host has been demonstrated for a coneworm in southern pines (Asher 1970) and for ponderosa pine cone beetle (Kinzer et al. 1972).

What methods of pest control are available for use?

Insecticides are the only practical control agents currently available for cone and seed insects and other insect pests in orchard situations where need for control is immediate. However, cultural practices in orchards can have effects. The importance of orchard site selection has already been pointed out and the effects of cone removal on populations of cone and seed insects should not be underestimated. It is important to collect all cones in an orchard, including cones on graft rootstocks; otherwise, an on-site population will exist, resulting in higher losses. For example, in 1979, in a Douglas-fir seed orchard where cones on rootstocks were not collected in 1978, cone and seed insects destroyed 1.7 times more potential seeds than at another orchard less than 2 km distant where all cones were collected in 1978. Insect-resistant clones have been identified in southern pine orchards in the United States (Merkel et al. 1965; Merkel 1967; DeBarr et al. 1972). Presence of resistant clones in orchards could reduce the dependence on insecticides. Unfortunately, a survey of two Douglas-fir seed orchards in B.C. indicated that clonal variation in susceptibility to several cone and seed insects was not of practical significance (Hedlin and Ruth 1978). Treating Douglas-fir with cold water to delay reproductive bud flush, for prevention of pollen contamination (Silen and Keane 1969; Fashler and Devitt 1980), has reduced damage by Douglas-fir cone gall

midge, but the effectiveness of the technique varies from year to year and cannot be relied upon.

The strategies of applying control actions depend on the type of action to be taken. The following is concerned specifically with application of insecticides since these are the only practical agents currently available for use in most situations.

Strategies for applying insecticides

Strategies for applying insecticides involve the following questions:

1) Which insecticide should be used?
2) How should it be applied?
3) When should it be applied?
4) Which tree should be treated?

The insecticide actually chosen will depend on the insect to be controlled, which insecticides are registered for use against that particular insect, when application can be made, and location of the orchard. The lack of registered insecticides for use against specific insects greatly restricts the strategies that can be developed for use. Only one insecticide (dimethoate) is registered for use against cone and seed insects in Canada (excluding defoliators that attack cones) and then only on one host (Douglas-fir). Orchard location can also restrict strategies, especially when an orchard is located near or adjacent to sensitive areas, such as residential areas, schools and reservoirs.

Insecticides can be grouped into contact insecticides and systemic insecticides. Each group has characteristics that affect the strategy of their use.

Contact insecticides must contact the insect to be effective. Thus, they must be applied when the insects are exposed. They are not effective against stages of insects that live within protected environments, such as cones. Timing of application is critical when controlling cone and seed insects, but not as critical when controlling insects that are constantly exposed, such as defoliators and aphids. In the case of Douglas-fir cone and seed insects, contact insecticides must be applied when strobili are open and adult insects are active to be effective and, therefore, can only be used as preventative sprays because there is no time to monitor for the need of pest control. Azinphosmethyl (Guthion®) is used in southern U.S. pine orchards to prevent infestations of coneworms (Dioryctria spp.) (Merkel et al. 1976), especially the webbing coneworm, one of their major pests. This insect overwinters as young larvae in sheltered niches, such as branch crotches, and infests cones once these larvae become active in the spring. The insecticide must be applied when the larvae become active but before they enter cones, a period of a few days.

Systemic insecticides, which are taken up by plant tissues, have advantages over contact insecticides for control of cone and seed insects; namely, that timing of application is not as critical and that systemics are less susceptible to wash-off by rain. Use of a systemic in Douglas-fir orchards allows time to monitor orchards for the need of pest control. A disadvantage of systemic insecticides is their relatively high toxicities to nontarget organisms, including trees. Operational applications of dimethoate in Douglas-fir seed orchards have shown some clones to be sensitive to, i.e., severely damaged by, a concentration of 0.5% active ingredient. The range of concentrations used in orchards for effective control of cone and seed insects is 0.5 to 1.0%.

Spraying is the only method of applying contact insecticides. Systemic insecticides can be applied as foliar sprays, paint-ons, injections, granules incorporated into the soil, and soil drenches, depending on formulation. Only foliar sprays and soil-incorporation of granular formulations have been developed adequately for operational use.

Sprays can be applied with hydraulic sprayers, mist blowers or airblast sprayer. Hydraulic sprayers, the type used in Douglas-fir seed orchards in B.C. for cone and seed insect control, apply high volume, low concentrate sprays which can be selectively directed to cone-bearing portions of tree crowns, resulting in good coverage. Good coverage is important if systemic insecticides applied as foliar sprays are to be effective against cone and seed insects (Hedlin 1966; Johnson and Zingg 1967) because, although systemics are taken up by plant tissues, they are not translocated far. Mist blowers and airblast sprayers apply low volume, high concentrate sprays. These sprayers can apply a spray to an orchard more rapidly than can hydraulic sprayers, but the sprays contain more concentrated active ingredient and are more susceptible to drift because of the small droplet sizes produced. Mist blowers and airblast sprayers are used in southern U.S. pine orchards for application of contact insecticides for control of webbing coneworm and other seed pests. These sprayers are often more efficient than hydraulic sprayers for control of defoliators and other exposed insects.

Aerial applications of contact insecticides for controlling orchard pests are being tested in the southern U.S. and show promise, but development of this technique is not complete (Barry 1981). A problem of aerial applications is the poor spray distribution that often occurs.

Timing sprays of systemic insecticides is a function of the tree species involved. The optimum time for treating Douglas-fir is when the conelets are closed and turning down, but before they reach the pendant position. Sprays applied before or after this period are not as effective. The optimum time for spraying spruce is after the conelets have closed and are just starting to turn down, but before they reach the horizontal position. Optimum spray times for other conifers have not been determined.

Granular insecticides are used operationally in the southern

pine orchards, primarily for control of seed bugs and tip moths (Merkel and Hertel 1976; DeBarr 1978; Nord 1978). Single applications of granular insecticides can be as effective as several sprays in reducing damage by these pests (DeBarr et al. 1972; Neel 1980). These insecticides, which are applied in the spring when the sap begins moving in the trees, give season-long control and are particularly useful against insect pests that produce several generations a year. A disadvantage of granular insecticides is their high toxicities to nontarget organisms, including mammals and especially, birds. Because granular insecticides are applied before insect attacks take place, they can only be used as preventative measures. In the southern U.S., they are used in orchards that have had histories of seed bug or tip moth infestations.

The effectiveness of treating orchards with single sprays are often adequate for insects, such as defoliators or aphids; but for control of cone and seed insects, the effectiveness of single sprays depends on the variation of reproductive bud flush. Variation in strobili development in Douglas-fir can range up to 9 days on a single tree (Allen 1943). Cones on one tree may be pendant while on another they may still be open. Two or three applications, spraying each tree only once, when conelets are at the optimal stage of development, may be necessary to ensure an effective treatment.

Treatment should aim only at producing trees, and possibly only at the heaviest producing trees, depending on seed value. It is not uncommon for 20% of the producing trees to produce 80% or more of the cones, especially in young orchards that are just beginning to produce cone crops. Treating only moderate and heavy cropped trees maximizes the benefit/cost ratio for the insecticide application by reducing the amount of insecticide used and the amount of labor required to apply the spray while protecting the bulk of the crop. This is the approach currently used in Douglas-fir seed orchards in B.C., and has been suggested as a good approach for use in pine orchards in the southern U.S. (Yates 1977).

## CONCLUSIONS

Insecticides are currently the only practical agents for controlling insect pests in seed orchards where need for control is immediate. An expanded arsenal of insecticides for use against cone and seed insects in seed orchards is needed because only one insecticide is registered for use against cone and seed insects (excluding defoliators) and only for use on one host. The strategy used for control of seed orchard pests will vary among orchards, depending on the location of the orchard, on the insects causing damage, on which insecticides are registered for use against the insects of concern and on how these insecticides are formulated. Techniques for measuring crop size and for predicting seed losses to insects must be developed for the judicious use of insecticides.

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# WEYERHAEUSER'S SEED ORCHARD PROGRAM

C.J. Masters

*Western Orchards Manager*

*Weyerhaeuser Company*

*Centralia, Washington, U.S.A.*

## ABSTRACT

A description of Weyerhaeuser's Douglas-fir orchard program on the West Coast is presented. Emphasis is placed on genetic considerations, management philosophy and flower stimulation. The program objective is to maximize genetic gain per unit time. Therefore, the orchard type chosen was clonal; the design a randomized complete block. The importance of proper spatial distribution of the orchard, and of breeding zones and ramets within are discussed, as were the problems of clone number and roguing levels. Concerning management, three phases, establishment, growth and production are discussed. For establishment, the major issue is the cost of delays. In approach, with the advent of compatible rootstock, field grafting offers a time and growth advantage, since rootstocks can be developing root systems in the field while decisions on scion source are pending. The growth phase emphasizes maximum height growth and crown volume, not only to reach production targets quickly and maximize production, but in preparation for height control. In addition to developing crown volume, culturing for maximum internode length maximizes long-term yield by allowing greater light penetration, a key element of any height control procedure. Other components of the growth phase are also discussed. The focus of the discussion of the production phase is flower stimulation. Examples of recent Weyerhaeuser data illustrate the stimulatory effect of fertilization, girdling, root pruning and gibberellins. For each, yield increases of 2.5, 2.1, 5.2 and 3 times, respectively, were observed.

## RÉSUMÉ

On présente une description du programme de vergers à graines de Douglas taxifolié de la compagnie Weyerhaeuser sur la Côte Ouest. L'accent est mis sur les aspects génétiques, les concepts d'aménagement et l'induction florale. L'objectif de ce programme est de maximiser l'amélioration génétique par unité de temps, et, pour cela, il faut un verger de type clonal entièrement constitué de blocs aléatoires. On discute de l'importance de la disposition du verger, des zones de reproduction et des ramets qui s'y trouvent, ainsi que de la question du nombre de clones et de la quantité de rebuts de sélection. Pour ce qui est de l'aménagement, on analyse trois des étapes: l'établissement, la croissance et le rendement. Le principal problème de l'établissement est le coût d'attente. Un façon d'y remédier, maintenant qu'il est possible

d'obtenir des porte-greffes compatibles, est de faire le greffage au champ; cette méthode est avantageuse du point de vue temps et croissance parce que les racines des porte-greffes peuvent se développer en attendant le choix de la source des greffons. En ce qui regarde la croissance, c'est la hauteur maximale et le volume de la couronne qui priment, non seulement pour atteindre rapidement les niveaux de rendement visés et obtenir un rendement maximal, mais aussi pour pouvoir contrôler la hauteur. En outre d'augmenter le volume de la couronne, la culture visant à obtenir la plus grande distance internodale laisse pénétrer la lumière davantage, ce qui porte à son maximum le rendement à long terme et constitue un élément essentiel de toute méthode de contrôle de la hauteur. On discute aussi d'autres sujets relatifs à la phase de croissance. L'exposé sur la phase de production porte surtout sur l'induction florale. Des résultats obtenus récemment par la compagnie Weyerhaeuser montrent l'effet stimulant de la fertilisation, de l'annélation, de l'élagage des racines et des gibbérellines, avec des rendements accrus de 250,210,520 et 300% respectivement.

## INTRODUCTION

When I was asked to discuss Weyerhaeuser's Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seed orchard program on the west coast, it seemed that our approach to design, establishment and management of seed orchards was not unlike that of many organizations. Therefore, what should the focus of this paper be? There is not time to discuss the specific details of each and every aspect of the program. Instead, I have chosen to describe our management philosophy and discuss the reasoning behind it. Also, since flower stimulation techniques are one of our most important management tools, it is appropriate to focus on this aspect of the program as well. To that end, examples of Weyerhaeuser data for the four major stimulation techniques (fertilization, girdling, root pruning and gibberellins) are discussed. Overall, the objective of this paper is simple. That is, to present a point of view, stimulating questions and discussions, that will help in developing an orchard program. Emphasis is on the first generation only.

Any given management approach is based on a set of objectives and an ability to meet those objectives. Therefore, before reviewing Weyerhaeuser's approach, some background information is helpful. Our tree improvement programs on the west coast headed into full swing in 1965. The objective was to obtain additional product value through optimal selection of species, seed source, families and individuals within families. The system chosen to meet this objective was genetic recurrent selection. In 1967, the initial first-generation seed orchard ramets were planted at Rochester, Washington and Turner, Oregon. In 1973, additional acres were established at Sequim, Washington. Today, Weyerhaeuser manages 69.2 hectares of Douglas-fir orchards, producing seed for 11 breeding zones. The regeneration requirement through 2004 is on the average 16,200 hectares per year across 1.13 million hectares in Washington and Oregon. The average age of the oldest orchard is now 13 years. In terms of meeting planting stock requirements, there should be

an abundance of seed for some breeding area; for others a potential shortage.

The objective of our orchard program is basically two-fold. That is, to produce large quantities of seed, and to maintain the proper genetic quality control to assure predicted genetic gains become realized gains. The latter is by far the more important; yet, the most difficult to achieve. Therefore, in describing our philosophy and approach it seems fitting to quickly touch on the genetic considerations before delving into management practices.

## GENETIC CONSIDERATIONS

Preliminary planning is an extremely important phase in the development of a seed orchard program. Several questions need to be answered. For example, when is the seed needed? What is the production capability? What is the planting stock requirement by breeding zone; perhaps seed zone or elevation band? Once these questions have been answered, important design questions need to be considered. The first question generally asked concerns the type of orchard -- seedling or clonal? The type selected depends on the situation. Our choice was clonal because the approach offers the following advantages:

1) Parents are of known combining ability.
2) Roguing or other spacing adjustments can be made when needed.
3) Inbreeding should be less.
4) Offers a means to preserve genotypes.
5) Orchards can be placed on sites conducive to seed production, etc.
6) Orchards can be cultured for seed production.
7) Flowering generally occurs earlier.

We have opted to keep the testing and seed production functions separate. By so doing, and with the clonal approach we expect to produce seed capable of maximum gain.

The design question is usually the next issue. Giertych (1975) in the text Seed Orchards, edited by Faulkner, offers a number of design options. There are many suitable designs. However, only those designs which minimize selfing and favor panmixis should be considered. Hence, our choice of the randomized complete block design, which meets both criteria. Also, it lends itself to valid clonal comparisons and to performing replicated experiments. Once the site has been selected, orchard layout questions need to be resolved. The major issue is pollen contamination. All too often we have seen examples of orchard blocks established on unsuitable sites, or blocks representing different breeding areas placed too closely together. The reasoning has been either to save space or because the acres were not available. We have our own examples of poor layout, but it is not the way it should be done. Seed orchards can become a costly embarrassment if predicted gains are not realized. Therefore, our approach will be to do the best job we can to minimize pollen contamination through proper spatial distribution of

orchard blocks and isolation of the orchard itself. Our philosophy is -- it's better to be safe than sorry. Until we have strong evidence that pollen contamination is not a serious problem, or have consistent treatments to minimize its effects, like bloom delay and supplemental pollination, we will consider dollars for isolation well spent. The generally accepted width of an isolation strip is 122 meters. Some evidence suggests this is ample; some does not. It goes without saying that the distance between ramets of the same clone needs to be as large as possible. This applies to individuals within families as well. Again, the generally accepted standard has been 27 meters.

The last issue discussed will be that of clone or genotype number. The size of the breeding and production populations is completely different. The breeding population carries all genotypes required to move through time without unduly narrowing the genetic base. The production population does not. Since orchard management is costly, carry only enough clones to meet the following objectives:

1) To provide a representative sample size (selection) capturing the genetic diversity of the breeding area and later gain through roguing.
2) To provide a representative sample of the breeding area (after roguing) from which production and later performance will be based (reasonable genetic base).

So, what should the number of clones be in the final production population? Some feel 10 is ample; others feel more comfortable with 30 or 40. For now, it is still a good question. Our current thinking is that 20 is ample, but it is still based somewhat on professional intuition.

Concerning roguing levels, based on an examination of our progeny test data definitely plan for at least a 50 percent rogue. However, do not put yourself into a box during the design phase. Plan for a high roguing level. It is much nicer to have the option to remove clones, than wishing others were available. For example, it is less costly to build an "elite orchard" through roguing than by establishment. In the same vein, by not establishing enough ramets per clone, to allow for silvicultural thinning, or by limiting spacing, you can again put yourself into a box. Progeny test information seems to notoriously lag behind orchard development. Roguing to maintain ramet productivity in the future without the benefit of progeny test information can also be a costly embarrassment. Our choice would be to initially increase the number of ramets per clone, allowing for a silvicultural thin, and reaping the benefits of early production. However, each situation is different. Nevertheless, two key words are flexibility and box. You can keep yourself out of boxes by maintaining flexibility. It is good to keep in mind that sound selection, breeding and testing buy you nothing in terms of realized gain if your orchard program is not sound.

## ORCHARD MANAGEMENT

There are three phases of orchard management: establishment, growth and production. The approach to each is to discuss them separately with emphasis on the production phase; specifically, flower stimualtion. Also, the intent is not to get bogged down with nitty-gritty, but to focus on the overall philosophy.

### Establishment Phase

Generally, the establishment phase lasts one to four years. The thinking being that a tree planted later than that would be too far behind to compete successfully from a production point of view -- at least at current orchard spacings. With the use of compatible rootstock, there is some truth to this line of thinking; with wild rootstock, not so. Graft incompatibility creates holes in orchards. With these holes also comes the opportunity to move in ramets of top performing clones. It never fails, these ramets always seem to find themselves next to each other in the orchard. To rogue them means a loss in production and genetic gain; to leave them would mean considerably less yield among all competing ramets. The cost of a transplanting operation would quickly be recovered in terms of increased seed and genetic gain. Again, it points out the critical relationship in timing between the progeny test and orchard. Although the competition issue offers interesting debate and opportunity, the real issue is the cost of delaying establishment. Each year establishment is delayed means a delay in getting improved stock to rotation.

There are two common establishment techniques used. In the first, grafts are made on 1- to 2-year-old potted rootstock. Outplanting follows in the fall or the next spring. In the second, grafts are made on field-grown rootstock 2 to 3 years after planting. Our efforts with the potted rootstock approach have been successful. With this approach high grafting success is assured and establishment flexibility maintained. A drawback of the potted system is that if grafts become pot-bound, poor performance can result. Growth rate is reduced, plagiotropism seems to be accentuated and, later, wind firmness may be affected. Nevertheless, it is our preferred method of establishment.

We are, however, looking very hard at grafting on field grown stock. There are two major reasons why this approach is appealing. First, grafting on stock with well-developed root systems should offer a growth advantage. This fact is well established. One spin-off of this increased growth should be earlier flowering. Secondly, there is a time advantage. Rootstocks can be growing in the field while decision on scion source are pending. The technique is well suited to a breeding orchard situation, where growth, flowering and time are considered important. Weyerhaeuser is currently using the approach in its breeding orchard at Sequim, Washington, and is planning its use in advanced generation orchard establishment. The major drawback to this sytem would have to be increased risk of poor graft survival due to the chance of unfavorable climatic conditions during grafting. To date, however, this

has not been a significant problem with Douglas-fir on the west coast.

Growth Phase

Although flowering is limited during the growth phase, there is opportunity to culture for maximum growth. Three advantages quickly come to mind. These are:

1) To reach full production targets as quickly as possible.
2) To develop a crown capable of maximum cone production (long internodes), and
3) To develop a crown that will minimize reduction in yield following height control (again, lengthy internodes).

The third advantage may be more important than many realize. Harvesting cones from tall trees is costly. Results from Weyerhaeuser research on height control at our McDonald orchard indicated no difference in yield ( = 0.05 level) between control ramets and those height controlled, for both the 1978 and 1980 crops (Masters, unpublished data). The paired-plot study involved 12 clones with one ramet per clone per treatment, chosen for their similarities in height and crown volume. At the time of height control, the average height of control ramets was 13.7 meters, of those height-controlled, 6.7 meters. Although the study was small, the redistribution of flowering seen on height-controlled ramets was responsible for the comparable yields on those ramets. Larger studies have been installed. Therefore, in addition to developing crown volume, culturing for maximum internode length maximizes long-term yield by allowing greater light penetration, an important element of any height control procedure.

Still, there are many unanswered questions about how to maximize the growth of Douglas-fir. Fertilization is obviously an important treatment. A Weyerhaeuser technical report "The principles and practice of nutrition in Douglas-fir seed orchards" (Masters and Webster 1980) summarizes the state of the art on Douglas-fir nutrition for growth. The information in this report offers guidelines on monitoring nutrient status as well as developing the fertilizer prescription. Overall, our objective is to maintain nitrogen, phosphorus and sulfur at high levels and the other micronutrients at medium levels. Also, the micronutrients are not allowed to reach critical levels. Irrigation is another treatment that can be used to improve growth. Some sites require it; others do not. Concerning a specific prescription, we have none. When our soils dry we water to field capacity. Our most frequently used monitoring device is the Pressure Bomb[1]. Other cultural practices have been used from time to time, depending on the situation — viz. subsoiling and weed control. Subsoiling improves aeration of heavy soils or those heavily compacted. Weed control, again depending on the situation, can reduce competition for light or moisture. It can also provide some rodent protection.

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[1] PMS Instrument Company, Corvallis, Oregon

Before moving on to the production phase, another question that must be asked -- when does culture for growth shift to production? There is no specific point at which the shift should occur. The decision should be made based on ability to meet planting stock requirements. This means pooling information on orchard stocking levels, site productivity and response to stimulation treatments. For some, it might be at the point Douglas-fir begins producing significantly, which is generally between the ages of 10 and 12. These ages will, of course, vary and depend on site and the successful culture for growth. Others, and Weyerhaeuser currently fits into this group in some situations, may feel the need to wait until larger crown volumes are attained before beginning a stimulation program. The concern is that reduced height growth (a characteristic of flower stimulation treatments) will foster development of compact crowns reducing future yields. Production then occurs only on the outside edges of the crown because of poor light penetration. Still others may favor high density plantings, practicing stimulation early to obtain early yields. We are working toward this position in the future. We want our best material into the field quickly. Also, we have placed ourselves into enough boxes in the past. We want the flexibility to manipulate genetic gain and we want to keep our trees low. Whether we are talking about harvest, supplemental mass pollination or insect control, small trees are less costly to manage.

## Production Phase

"Production phase" to us means flower stimulation. And we are nearing this phase of our management. However, graft incompatibility, changing planting stock requirements and poor orchard site selection in one case, make it essential to carefully consider what we do. Our concern at the moment is that intensive flower stimulation too early will reduce growth and future yields. There is one exception. We do fertilize to stimulate flowering but only because the rates we use do not negatively impact growth. So currently, our focus is to learn as much as we can about what our flower stimulation practices should be. Therefore, the discussion of this section will revolve around examples of recent Weyerhaeuser data collected on each of the four major flower stimulation treatments: fertilization, girdling, root pruning and gibberellins.

## Fertilization

The practice of fertilizing Douglas-fir to promote flowering has been with us for some time. Various rates and types have been used. Generally, rates have ranged from 224 to 448 kg N/ha, with the nitrate form of nitrogen being the type most commonly used. Success has been varied, with fertilizer rate and type, site and tree age (maturation) all being important variables. Weyerhaeuser has not done any fertilization research since the mid-70's when the operational recommendation of 224 kg N/ha calcium nitrate was made. More is planned in the future because we do not feel we have the best prescription. Nevertheless, significant responses in flowering, even at low rates are possible. The data represents an operational check of the prescription and is based on individual production.

Table 1 illustrates the effect of calcium nitrate fertilization at 224 kg N/ha on the 1980 crop at Turner, Oregon (Masters and Dotter, unpublished data). Half the Coos Bay and Springfield low-elevation blocks received fertilizer in 1979. As a result of this treatment, the difference between fertilized and control groups was striking. Significant increases in yield can be seen for all production traits (Table 1). However, the most striking difference was in the total cones. The percent increase in total cones for the 12-year-old Coos Bay block and the 11-year-old Springfield block was 145 and 59 percent, respectivly. In terms of actual numbers, the Coos Bay block produced an additional 69,498 cones; the Springfield block, 44,427 cones. Not only did the treatment increase the number of trees producing, but also the yield on those destined to flower. Had the size of the 1980 crop been predictable in the spring of 1979, and the whole orchard fertilized rather than half, an additional 3.3 kg/ha of good seed would have been produced in the Coos Bay block alone. Thus, a total yield for Coos Bay of 16.5 kg/ha would have been a very respectable yield for a 12-year-old orchard.

Table 1. The effect of calcium nitrate fertilization (224 kg N/ha) on cone production at Turner, Oregon[1].

| Trait | Coos Bay Block (CB) | | Springfield Block (SP) | | Percent Increase | |
|---|---|---|---|---|---|---|
| | Fertilized (N=494) | Control (N=495) | Fertilized (N=650) | Control (N=650) | CB | SP |
| Total Cones | 117,472 | 47,947 | 119,989 | 75,562 | 145 | 59 |
| Producing Trees | 243 | 162 | 285 | 217 | 50 | 31 |
| Cones/Prod. Tree | 483 | 296 | 421 | 348 | 63 | 21 |
| Cones/Tree | 238 | 96 | 184 | 116 | 148 | 59 |

[1] 1980 Data: Coos Bay age 12; Springfield, 11.

Girdling

Girdling should be considered a viable flower stimulation tool in seed orchards. Based on past Weyerhaeuser research and that of others, yield increases of 1.5 to 2 times are not unreasonable. In 1979, a pilot girdling trial was initiated at Turner, Oregon, and Rochester, Washington. Its purpose was to determine flowering effectiveness on a large scale, and to help determine long-term application strategies.

The study was designed to compare ramets treated with an overlapping half-circumferential saw girdle (main stem) to ungirdled (control) ramets. The distance between the girdles was set at 1.5 times the diameter of the stem. Eight rows in each orchard were selected for girdling, and an additional 8 were treated as controls (= 250 ramets/ treatment/orchard). All study trees selected were relatively uniform with respect to growth with no signs of graft incompatiblity. Included

in the study were plans to assess the effect of yearly girdling and alternate year girdling. First-year results (1980 crop) were again striking (Masters and Ross, unpublished data). Yield increases in total cones produced were 78 precent at Turner, Oregon, and 115 percent at Rochester (Table 2). Increases in yield seemed equally split between increases in total producing trees as well as in cones per producing tree. In addition, significant increases in male production were noted (not shown).

Table 2. The effect of girdling on cone production at Turner Oregon and Rochester, Washington[1].

| Trait | Turner (CB) Girdling (N=256) | Control (N=255) | % Inc. | Rochester (LV) Girdling (N=276) | Control (N=271) | % Inc. |
|---|---|---|---|---|---|---|
| Total Cones | 34,405 | 19,322 | 78 | 26,807 | 12,526 | 114 |
| Producing Trees | 117 | 86 | 36 | 92 | 54 | 70 |
| Cones/Prod. Tree | 294±39[2] | 225±50 | 31 | 291±53 | 232±52 | 25 |
| Cones/Tree | 134±19 | 76±18 | 76 | 97±20 | 46±12 | 111 |
| Cone Effic. (%) | 66±6 | 70±10 | — | 88±3 | 80±4 | — |

[1] 1980 data: Turner age 12; Rochester, 11.
[2] Standard error.

Root Pruning

Root pruning with a Vermeer tree spade or subsoiling has become a standard flower stimulation treatment in many orchards. Examination of the state of the art shows the potential exists to at least double yields. In fact, a quadrupling of yields is not unreasonable. For example, in 1974, a study involving two root pruning treatments and a control was initiated on 7-year-old grafted Douglas-fir at Rochester, Washington (Masters et al. 1981). Root pruning was achieved by fully extending all four blades of a 762-mm Vermeer tree spade without lifting the tree. An early treatment (April 19, 1974) was timed to correspond with the beginning of vegetative bud swell; the late treatment (June 26, 1974), to the end of rapid shoot elongation. In all, each treatment involved an average of 2.5 ramets from each of 20 clones. The results indicate that 74 percent of the early root-pruned clones produced female cones and 54 percent produced male buds (Table 3). The percent of clones flowering in the control group was 22 and 20 percent for female and males, respectively. Early root pruning significantly (0.05 level) increased the number of female cones per cone-bearing ramet, female cones per ramet and male buds per ramet 5, 34 and 9 times respectively. Filled seed per cone was not affected by treatment. Based on the evidence, root pruning has been recommended as a flower stimulation treatment in breeding and seed orchards. However, work continues on a more cost

efficient approach to this treatment -- subsoiling.

Table 3. The effect of root pruning on the production of female cones and male buds in the Longview block at Rochester, Washington[1]

| | Percent Clones producing | | Female Cones/ producing ramet | | Female Cones per ramet | | Male Buds per ramet | |
|---|---|---|---|---|---|---|---|---|
| Treatment | Females | Males | n | $\bar{x}$ | n | $\bar{x}$ | n | $\bar{x}$ |
| Early root pruning | 74 | 54 | 22 | 120a[2] | 41 | 68a | 41 | 520a |
| Late root pruning | 43 | 37 | 8 | 4b | 41 | 1b | 41 | 5b |
| Control | 22 | 20 | 15 | 23b | 196 | 2b | 196 | 60b |

[1] 1975 data; graft age 8
[2] Values with the same letter do not differ significantly ( = 0.05)

Gibberellins

The research on gibberellic acids (GA) to promote flowering in Douglas-fir and other species has been extensive. The literature on this subject is ample. The work at Weyerhaeuser was pioneered by S.D. Ross, and the results have been successful. A testimony to that success is our use of stem-injected $GA_{4/7}$, $GA_{4/7}$ + girdling and $GA_{4/7}$ in combination with other treatments operationally in our breeding orchard. When these treatments have been applied to young ramets (3 to 4 years old), they have made the difference between having a crop and not having one.

Our concern now is to expand this technology for use on large production orchard trees. Research on the "cut-branch" method of injecting GA into large trees has been successful (Masters, unpublished data), but the method is labor intensive and has other drawbacks as well. Foliar application of GA is our goal. The initial work at Weyerhaeuser by Ross (1979) was successful. Individual branch treatments to 9 year old Douglas-fir grafts resulted in 27 percent of the branches yielding females, and 15 percent males. Controls bore no flowers of either sex.

In 1978, in support of Ross' work, I initiated additional work on foliar application of GA. The objective was to confirm the response obtained with individual branch sprays by treating whole trees. The study, a clonally balance paired test, involved 10 weekly applications of foliar $GA_{4/7}$, and a control. The treatments were applied to 8 clones and 4 ramets per treatment per clone, in the 8-year-old Cascade block at Rochester, Washington. Both clone and treatment sources of variation were significant at the 0.01 level. The control mean was

81 ± 45 (S.E.) flowers and yielded a total of 2352 harvested cones. For the spray treatment, the mean was 246 ± 79 flowers, producing a total of 6942 harvested cones. The response was clearly, a 3-fold increase (Table 4). The data are self-explanatory. The most significant impact was in the number of clones and ramets flowering. However, there was also a significant increase (62 percent) in the number of cones per producing tree. Also, no significant difference in cone or seed efficiency was observed. It is acknowledged that improvement in the time and duration of treatment is needed to make large-scale foliar spray applications less costly. Also, work on method of application is needed. Some of this work is ongoing. It is clear that foliar application of GAs in seed orchards is near at hand.

Table 4. The effect of GA foliar spray on cone production in the Cascade block at Rochester, Washington[1].

| Trait[2] | Control (N=32) | Foliar Spray (N=32) | Percent Increase |
|---|---|---|---|
| Total Cones | 2,352 | 6,942 | 195 |
| Producing Trees | 11 | 20 | 82 |
| Percent Producing Cones | 63 | 100 | 59 |
| Cones/Producing Tree | 241±112 | 347±98 | 62 |
| Cones/Tree | 74±41 | 217±68 | 193 |
| Cone Efficiency (%) | 91 | 88 | --- |

[1] 1979 data; graft age 8.
[2] Treatments were significantly different at the 0.01 level.

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# STRATEGIES

# FOR

# TREE IMPROVEMENT

Chairman:

John Barker
Western Forest Products Ltd.
Victoria, B.C.

# DECISION MAKING AND STRATEGY OPTIONS FOR TREE IMPROVEMENT

D.T. Lester

*Crown Zellerbach*

*Wilsonville, Oregon*

## ABSTRACT

Procedures for tree improvment are examined in relation to the common management activities of planning, implementation, and control. Planning calls for a clear and acceptable enunciation of purpose, a decision on how to select strategies, identification of strategy options and their subsequent evaluation, and a consideration of risks associated with the chosen pathway. Implementation is effected through training, although it is expedited if planning procedures are properly explained to all parties when several organizations are involved. Similarly, control is favoured by commonly recognized objectives and a sense of mutual commitment.

## RÉSUMÉ

On étudie les méthodes d'amélioration des arbres en considérant les étapes normales de l'aménagement: la planification, la mise en oeuvre et la conduite de projet. La planification exige que le but soit exposé de manière claire et acceptable; il faut décider de la façon de choisir les stratégies, déterminer lesquelles on peut employer, en faire l'évaluation et calculer les risques que comporte le choix qu'on fait. La mise en oeuvre se fait par l'apprentissage, bien qu'elle puisse être accélérée si les méthodes de planification sont bien expliquées à tous et chacun lorsque plusieures organismes sont en cause. De même, la conduite du projet est facilitée si tous s'entendent sur les objectifs et considèrent qu'ils font partie d'une équipe.

## INTRODUCTION

The word "strategy," stripped of its original military meaning, can be defined as a plan for the skillful management of any enterprise. At first glance, tree improvement appears to require only a simple plan. On further consideration, as the complexities of gene pool formation, biology of seed production, uncertainties of cost and benefit, and problems of long-term commitment are unveiled, we see that there are many possible strategies for this complex enterprise. Choices among options become necessary as does the need to organize information in ways that facilitate decisions.

Subsequent speakers will present some specific strategies. In preparation for those discussions, I have chosen to emphasize management of the process by which strategy options might be evaluated.

Management is often symbolized by the sequence of activities shown in Figure 1. Let's consider how the way in which strategy options are chosen might influence the success of those activities.

## PLANNING

At a recent meeting of tree breeders, a silviculturist remarked that there is an attitude of "true belief" among breeders; an attitude sometimes undaunted by economic realities. Our symposium reflects the view that tree improvement starts at the indicated point in Figure 2. It should be pointed out, however, that tree improvement has a better chance of maintaining the required long-term commitment if the choice to develop a program has been made after a comprehensive review of options in intensive forest management. Challenges to preceding steps in the path leading to a tree improvement program are immensely frustrating.

In planning skillful management, I see five general questions to be asked:

1. What is the purpose of a particular tree improvement program? A few forestry managers seem to still accept a reply of "to achieve genetic gain." Increasingly, however, an answer of "to develop an investment opportunity that compares favorably with alternative investments" probably will be more acceptable in both public and private organizations.

2. How shall we choose what to do? Here I refer to the process of decision making. Although the basic phases of selection, propagation, and orchard establishment are reasonably obvious, variations on the general strategy of tree improvement are numerous and can be complex.

   One way to choose a tree improvement strategy is to follow the leader. This often appears to be the choice of forest industry and probably is optimum where the leader has a good strategy which matches the needs of followers.

   At levels of greater participation in tree improvement planning, more careful analysis is required. That analysis should begin with the identification of which factors are important in evaluating alternative strategies. Gain per year, years to seed yield, progeny test acreage, total cost, etc. are examples of criteria by which to measure alternatives. Having a common set of negotiated criteria does much to reduce arguments from disparate points of view.

3. What are the strategy options? Many of us do a less-than-comprehensive survey of alternatives in choosing a tree improvement strategy. Despite the fact that we usually are constrained by inherited programs, there are some non-traditional options that might be of value in some programs. Table 1 lists a few rarely considered possibilities, each of which is more or less technically feasible at

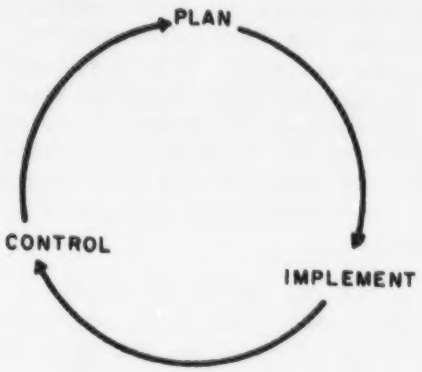


Fig. 1. Activities in management

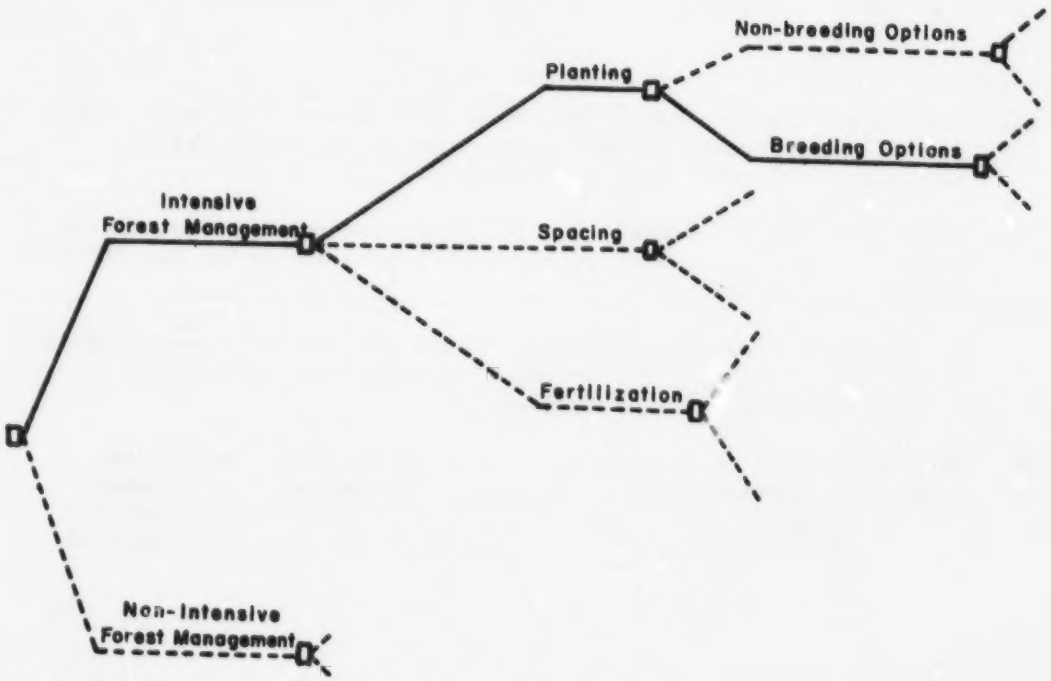


Fig. 2. A decision tree in forest management

present for some species or areas. Current rapid progress in cell biology research may soon open options that we easily dismiss today.

4. Having decided which criteria are important, and having arranged tree breeding options, the choice of which option to implement involves evaluating each option for each criterion. A variety of formal analytical techniques exist for this purpose. They include systems of numerical weighting, probabilistic decision trees, and matrices where only data (as contrasted to arbitrary scores) can be entered. Figure 3 shows portions of a criteria/alternatives matrix used to guide a choice of seed orchard type and location. Each of these techniques leads, in a systematic way, to the identification of a preferred alternative.

5. What might go wrong if the chosen alternative is followed? If risk is not included among the criteria by which alternatives are evaluated, an estimate of risk for the preferred option should be made. Risks in a high cost-high benefit approach, for example, would include chances of decreased funding at critcal times.

   Perhaps the intially chosen option will be seen to carry too much risk and a more conservative option will be chosen.

Table 1. Some non-traditional options for tree improvement.

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A. Bulk population breeding: Establish plantations with a desirable genetic base, ignore pedigree, rogue on basis of individual performance, utilize as a seed orchard.

B. Multiple Index Selection: Develop replicate populations, choose trees for seed production within that population which has the best combination of traits.

C. $F_2$ selection from wide crossing: Cross provenances, induce early flowering, produce an $F_2$, screen for exceptional segregants, propagate vegetatively or by seed.

D. Cell selection: Expose cultured tissues to selective forces, regenerate surviving cells, propagate vegetatively or by seed.

| CRITERIA | ALTERNATIVES: Field Orchard (4 location-ownership combinations) A B C D | Potted Orchard (1 location-ownership) E | Potted Field (5 location-ownership combinations) F G H I |
|---|---|---|---|
| SEED PRODUCTIVITY POTENTIAL | | | |
| Mean maximum temperature | | | |
| Mean moisture deficit | | | |
| FACILITIES COST | | | |
| Irrigation | | | |
| Growth system | | | |
| ORCHARD TREE COST | | | |
| Propagation | | | |
| Root Control | | | |
| Irrigation | | | |
| Fertilization | | | |
| Monitoring | | | |
| Protection | | | |
| Weather | | | |
| SEED PRODUCTION | | | |
| Chemical induction | | | |
| GENE DILUTION | | | |
| GAIN PER UNIT TIME | | | |

Fig. 3. Abstract of a criteria/alternatives matrix for choice of a seed orchard type and location.

## IMPLEMENTATION

Implementation in tree improvement is largely a matter of training where a resident tree improvement staff exists. More challenging is the case where implementation requires persuasion of people in other organizations. It seems to me that presentation of the process by which a particular tree improvement strategy was chosen could be useful in gaining support of those who implement the plan as well as those who provide administrative approval.

## CONTROL

Control is an activity which varies widely in degree among different organizations. Where a tree improvement strategy is implemented within one organization only, control ought to be fairly simple. By contrast, in cooperative programs, the range of knowledge and commitment among different partners would seem to require some standardization of critical activities. On-site inspection by a central tree improvement staff has been effective in some programs. Publication of standards for principal program activities has been useful in others. Perhaps the key elements here are related to those which have made Japanese industrial production the recent envy of the world, namely, a sense of common objectives and mutual commitment. Perhaps here again, formal processes of choosing options, openly presented, can be useful.

## CONCLUSION

Our next speakers will be discussing some specific strategies in tree improvement. I hope that my introductory comments will have been useful in helping us to relate those strategies to our own tree breeding programs.

# INTERIM SEED SUPPLIES BEFORE SEED ORCHARDS ARE PRODUCTIVE

**Yves Lamontagne**

*Ministere De L'energie Et Des Ressources*

*Service De La Restauration*

*Ste-Foy, Quebec, P.Q.*

## ABSTRACT

For most species in Canada, seed production in orchards falls short of the seed required for reforestation. Some measure of genetic control or gain is nevertheless attainable through appropriate choice of seed sources. Designation of seed zones or site regions is an important preliminary step in controlling seed movements.

The role and limitations of local provenances, tested provenance, tested stands, seed collection areas, seed production areas, and selected trees are discussed.

## RÉSUMÉ

Dans le cas de la majorité des essences d'arbres au Canada, les vergers ne produisent pas assez de graines pour répondre aux besoins des programmes de restauration forestière. On peut quand même obtenir un certain degré de contrôle génétique ou un certain gain génétique en faisant aun choix judicieux des origines des graines. Pour contrôler les déplacement de graines, il est important d'indiquer au préalable les zones au les régions d'où elles proviennent.

Cette communication discute du rôle et des limites des provenances locales, des semences et des peuplements certifiés, des zones de production et de récolte des semences, de même que des arbres sélectionnés.

## INTRODUCTION

Various tree improvement programs have been or are being developed all over Canada. One of the objectives of these programs is to develop improved genetic material that will be reproduced in production seed orchards.

For some species, a certain amount of improved seeds is already available. But for most species, it is expected that improved seeds from the orchards will be available in a certain number of years from their establishment, usually not before 10 years. Meanwhile, seeds and good seeds are needed by the billions to meet the requirements of the various artificial regeneration programs throughout the country.

It is imperative to get the best seeds possible for these programs because the small genetic gain achieved on one single seedling will become most important when repeated millions and millions of times. Various means of getting these seeds until seed orchards yield their full quota are suggested hereafter.

## SEED ZONES

One of the preliminary steps towards getting better results from artificial regeneration is to divide the province into seed zones or site regions (Ontario) based on climatic data or other factors affecting tree growth. In those zones or sites, the genetic characteristics of a given species are relatively uniform.

Unless there is strong evidence that seeds collected in one zone will perform satisfactorily in another zone, no seed movement between zones should be allowed. Seeds collected in one zone should then be used within the same zone or site region.

Most of the seeds actually needed in artificial regeneration programs are collected this way. That is, cones are picked from phenotypically good stands and kept separated by zone or even by some other subdivisions within the zone. Large seed lots are identified by stands within zone while smaller lots are bulked at extraction time, at least in Quebec. Non-identified seeds brought in by pickers should not be accepted at all.

## LOCAL PROVENANCES

A common conclusion from any provenance test is that "local seeds are best". This is so because trees have become adapted to the climate and environment in which they are growing through generations of natural selection. However, as for most rules there might be and in fact there are some exceptions. For example, other provenances than the local might survive and grow better when planted on the same site (e.g., the white spruce provenance from Beachburg, Ontario). If one is not aware of the extent of seed movement or if no research has been done in a given area or for a given species, the safe rule should be "collect locally". In that case, "local " seeds might be referred to as seeds collected in a township, an administrative unit, a small seed zone or any other convenient subdivisions of a territory.

Exact identification of the provenance should follow each seed lot from collection through extraction, seedling production and plantation in the field for future references. Here again, non-identified seeds should not be accepted.

## TESTED PROVENANCES

Geneticists have been actively engaged in provenance testing for many years now. They have shown what type of variation (clonal or ecotypic) can be expected throughout the range of a species. They have

also identified some provenance that will outperform the local one.

If the testing has been conducted over many years and if the original stand(s) tested is or are still available, large quantities of seeds can then be collected and be used with the local or instead of the local ones. Such stand(s) should also be reserved and managed for future abundant crops.

In that respect, as soon as a provenance gives some clues that it will be a good one, the stand should be saved from exploitation until more definite results are available. Too many good stands or provenances disappear during the lag period of testing.

## TESTED STANDS

Some provenances have tested or are testing better-than-average stands in order to provide an immediate source of well-adapted seeds. These tests are conducted at different locations in a province or part of a province. They will show which stands provide the best seeds for a given area. Seeds collected from many trees in these stands will be bulked and used either locally or at some other locations depending on the results of the tests.

Seeds collected from these stands will also provide valuable information as to seed movement within or between zones. The best stands so tested can be reserved and managed as seed production areas or seed collection areas. A greater genetic gain can also be expected if seeds are collected only on the best phenotypes in these tested stands.

## SEED COLLECTION AREAS

Seed collection in these areas is suited to such species as black spruce and jack pine which naturally occur in large, pure, even-aged stands and for which large quantities of seeds are needed annually for the artificial regeneration programs.

They are phenotypically good stands and they will provide large amounts of well-identified seeds with no or with a small genetic gain depending on the original quality of the stand. They may or may not have been tested.

Cone collection is generally done by felling a portion of the stand during a good seed year. It is generally recommended that a portion of the seeds be returned to the cut area in order to preserve the gene pool. Little or no management for increased seed production is generally done in these seed collection areas.

## SEED PRODUCTION AREAS

Seed production areas are phenotypically good natural stands or plantations of known origin in which some management practices have been conducted in order to increase their quality and their seed production.

If poor phenotypes are removed, genetic gains up to 10% might be obtained. Usually, these stands have been or will be tested. They are established in rather young but sexually mature stands in order to respond better to the cultural treatments.

Seeds may be collected from standing trees or from felled trees when the stands have become too old or too difficult to climb.

The tested seed production areas will provide the best seeds for artificial regeneration programs until improved seed is available from seed orchards. Such species as white spruce, white and red pine are best suited to this approach.

## SELECTED TREES

In an extensive plus-tree selection program as for black spruce and jack pine, a large number of phenotypically superior individuals are selected in various superior stands. These trees will be progeny-tested and the best families will be kept in a first-generation seed orchard. Since the selected trees are generally felled to ease cone collection, all cones can then be collected.

A portion of the seeds obtained from each of these can be taken, bulked and used for plantations. Usually, the amount of seeds available by that means will be rather small but they are another good source of well-identified superior seeds. Moreover, the plantations established with these seeds will provide, after being thinned of the poor phenotypes, and being managed for abundant seed crop, a future source of well-identified superior seeds.

## PURCHASING OF SEEDS

Purchasing seeds from commercial dealers can be tricky. Each agency needing seeds should have its own seed collection program. Nevertheless, if seeds must be purchased, make sure that you can trust the dealer or that you buy only certified seeds as to their quality and exact provenance.

## CONCLUSION

Many seed orchards have already been established for many species throughout the country and others are being set up every year. Many are still too young to produce seeds, do not produce enough seeds yet or do not flower properly. Meanwhile, large amount of seeds are needed annually.

For those organizations now working without seed orchards and that will continue to do so for many years, large amount of good seeds could be collected from seed production or collection areas, depending on species, established in each seed zone. If good provenances have been identified by proper experiments, seed should also be collected from those original stands if still available.

If no seed production or collection areas have been established or if reliable results from the provenance tests are not available, seed collection should be confined to the best phenotypically local stands in each zone and if possible, to the best trees in these stands.

Finally if a tree improvement program is underway for an organization, trees must have been or will be selected. Smaller quantities of good quality seeds can thus be obtained from these trees and used as partial fulfillment of a regeneration program.

# USES FOR ROOTED CUTTINGS IN TREE IMPROVEMENT PROGRAMS

**R. Marie Rauter**

*Silviculturist*

*Ministry of Natural Resources*

*Forest Resource Branch*

*Toronto, Ontario*

**and**

**J.V. Hood**

*Research Scientist*

*Ministry of Natural Resources,*

*Ontario Forest Research Centre,*

*Maple, Ontario*

## ABSTRACT

This paper presents a summary of the uses for rooted cuttings in various phases of a tree improvement program, namely breeding orchards, cutting orchards, production seed orchards, research plantations and production plantations. It also mentions some of the concerns regarding rooted cuttings as well as some of the problems that need solutions.

## RÉSUMÉ

Ce document résume l'usage qu'on peut faire des boutures racinées au cours de différentes étapes d'un programme d'amélioration des arbres, en particulier dans les vergers de reproduction, les verges de bouturage, les vergers de production de graines, les plantations de recherche et les plantations de rendement. Il fait également état de quelques points concernant les boutures racinées ainsi que de quelques problèmes à résoudre.

## INTRODUCTION

Vegetative propagation has long been employed in tree improvement programs, principally in the form of grafting. Much attention has been focused on the promise of tissue culture, but considerable development is still necessary before the promise can be fulfilled. Rooted cuttings are a third form of vegetative propagation, and the one on which this paper will concentrate.

Although several of the hardwoods, such as the Euramerican poplars (Populus x euramericana (Dode) Guinier), have been commonly propagated by rooted cuttings (Zsuffa 1976), Cryptomeria japonica (L.F.) Don is the only coniferous species propagated by this technique on a significant scale (Toda 1973). Recently there has been a pronounced increase in the use of rooted cuttings as a tool in tree improvement research and also as regular planting stock. The objective of this paper is to review the uses that rooted cuttings may serve in the various phases of tree improvement.

## BACKGROUND

In the late 1930's and early 1940's, several Canadians worked on the rooting of various coniferous species (Grace 1939, Griffith 1940, Farrar and Grace 1942). Although they did have some success, their programs were unfortunately discontinued due to World War II. In the 1960's, there was renewed interest in rooting in several species and in several countries throughout the world (Thulin & Faulds 1968, Rauter 1971, Kleinschmit et al. 1973).

This interest continued to grow and by the 1970's, it was felt that there was a role for rooted cuttings in tree improvement programs, provided that some major problems could be overcome. Two areas of major concern were: 1) determining the factors that influenced each species' rooting ability, and 2) the subsequent field performance of the rooted cuttings.

During the 1970's, symposia were held to discuss the success of rooting programs, to identify questions that needed answers and in some cases to provide answers to questions that had been asked. Two of the symposia, one in New Zealand in 1973, and one in Sweden in 1977, dealt entirely with the vegetative propagation of forest trees. (See references under 'Symposia'.) Many of the questions have since been partially answered, and many more are currently under investigation. Now, during the 1980's, a serious effort should be made to effectively incorporate rooted cuttings into tree improvement program.

## USES FOR ROOTED CUTTINGS

The uses of rooted cuttings can be assigned to five major areas on the basis of various objectives and procedures of research and management. The areas are: 1) breeding orchards, 2) cutting orchards, 3) production seed orchards, 4) research plantations, and 5) production plantations. The role of the traditional 'clone bank' is filled by both the cutting orchard and the breeding orchard.

### Breeding Orchards

The breeding orchard, as outlined by Rauter (1980), is designed to provide a source for producing new combinations of genes that will be suitable for advanced-generation programs. The trees in the breeding orchard may be representative of one or several of the following

objectives:

1) A reserve of clones occurring in the seed orchards for insurance against destruction by such agents as wind or fire;

2) Controlled pollinations to produce families for progeny testing and/or advanced-generation breeding;

3) A reserve of phenotypes that are not currently in the production orchard, but represent traits that may be useful in the future;

4) A reserve of plus tree selections of species that do not currently have a sufficiently large regeneration program to merit a production orchard;

5) Selections from certain exotic species as a source of pre-adapted genes for specific environmental conditions or with resistance to a given pest (Rauter 1980);

6) Samples of given gene pools that require conservation.

Although a clonal breeding orchard is normally established with grafted material, rooted cuttings can provide a viable alternative particularly when graft incompatibility is a problem. Since the number of ramets required per clone is small -- many fewer than for a production orchard -- good rooting ability is not important. Also, growth and form are not very important in a breeding orchard, thus cuttings do not have to be taken from young seedlings, but can be taken from older trees.

The management objective for the breeding orchard is to produce flowers for controlled pollinations. The trees should be subjected to flower inducing treatments such as fertilization, drought stress and hormone application. Since open pollinated seed is not utilized, the layout can be simple and systematic to facilitate the crossing work. Isolation from contaminating pollen sources is also not critical.

Cutting Orchards

The cutting orchard is designed to provide vegetative propagules of selected genotypes for current or future programs. The objectives may be the same as many of those listed above for breeding orchards. However, the management objective is to encourage vegetative growth and to promote ease of rooting through whatever technology is available.

The source material in the cutting orchard may consist of rooted cuttings, seedlings or grafts. Since the prime objective is to produce good quality cuttings for as long as possible, each cutting donor should be hedged, re-rooted or otherwise manipulated to retard maturation of the donor (Libby 1979, Libby and Hood 1976). The number of ramets per clone can vary from a few, when serving a clone bank function, to many when serving as a source of rooted cuttings for an artificial

regeneration program. This latter function assumes that a species has sufficiently good rooting ability in a juvenile state to make a production cutting operation efficient. The same advantages in terms of layout and location discussed for breeding orchards also apply to cutting orchards.

Production Seed Orchards.

The production orchard as outlined by Rauter (1980) is established to produce genetically improved seed that will fulfill the seed requirements of an artificial regeneration program. Seed from the orchard should produce seedlings that are suitable to the environment in which they will be growing. To meet this criterion, most orchards are established with material selected from the same geographic source or site region to which the seed or resultant seedlings will be returned. However, there are instances when a foreign source is superior to that of the local material. The selected genotypes that are placed in a production orchard have some or all of the desired traits currently required in a tree at harvest time.

Most clonal production orchards are established with grafted material, but rooted cuttings can provide the same viable alternatives as described under the previous section for breeding orchards. The selected individuals should root sufficiently well to produce the number of ramets required to satisfy the proposed planting plans for the production orchard. As in the breeding orchard, juvenile material is not necessary since flower production rather than growth rate is the main concern.

There are some programs considering the use of rooted cuttings for clonal production orchards. For example, workers in Sweden feel that rooted cuttings can be justified because the cost is 1/20th that of grafting, they can see no advantage of grafting over rooting, and they require much larger areas of seed orchards to be established than they have been able to plant to date through grafting (Werner 1977). The Texas Forest Service has experienced problems with graft incompatibility in slash pine (Pinus elliottii Engelm.) and loblolly pine (Pinus taeda L.). Rooted cuttings of clones selected for a wide range of compatibility and a positive influence on flowering will be used as rootstock for clonal production orchards (Bower 1981).

Research Plantations

The primary intent of research plantations with rooted cuttings is to obtain more precise genetic information than could be obtained with seedling experiments. The theoretical advantages of this approach include gains in selection efficiency (accurately identifying good genotypes), and more accurate estimates of genotype-environment interactions (Libby 1964, Burdon and Shelbourne 1974). Further, if heritability is low, the clonal trial will allow a smaller and more economical experiment to obtain a given level of precision (Burdon and Shelbourne 1974). These advantages also make rooted cuttings attractive for use in genetic architecture studies (Hood and Libby 1980).

Rooted cuttings can also be used to supplant the conventional seedling progeny trial (Libby 1969, Rauter 1980). Normally, wind-pollinated or control-pollinated seed is collected from individual clones, and seedling progeny tests are planted to evaluate the parent material. By rooting cuttings from the progeny, it is possible to multiply each seedling several-fold and to establish clonal trials rather than seedling trials. To establish a clonal trial the same size as the usual seedling trial, fewer seeds are needed per cross, thus the pollination effort can be reduced and the start of the testing program hastened.

Rooted cuttings can also be more efficient than seedlings in experiments designed to study growth rate, form, wood properties, fertilizer response, response to various treatments for induction of flowering, and similar types of physiological and genetic experiments. In certain experiments, the genetic variation within seedling families complicates the results. Conversely, the ability to partition variation in response to a treatment between and within genotypes, allows a cleaner interpretation of the results.

Since juvenile material is used for rooting, many if not most coniferous species are suited to this approach. Work currently under way in Ontario with such species as white spruce (Picea glauca (Moench) Voss), black spruce (Picea mariana (Mill.) B.S.P.), white pine (Pinus strobus L.) and tamarack (Larix laricina (Du Roi) K. Koch.), indicates that rooting ability of juvenile seedlings and the cuttings taken from first and second cycle cuttings is very high. Subsequent growth and form is comparable to if not better than seedling performance. Black spruce and tamarack are particularly amenable to this approach as they produce a great number of lateral branches when topped. Under contolled conditions, 100 cuttings per seedling donor have been obtained within a 12 month time span (Perez de la Garza 1977).

However, white spruce and white pine do not produce laterals as readily and the number of cuttings cannot be expanded as rapidly. Webb[1] (pers. comm. 1981) is investigating a variety of chemicals and environmental conditions and he has been able to increase several-fold bud differentiation and lateral branch development in white spruce.

Production Plantations

Production plantations are established to regenerate lands and to provide the next crop of trees. Conventionally, plantations are established with either seed or seedlings. Some exceptions were the planting of either rooted or unrooted cuttings of several Populus and Salix species throughout Europe and North America, as well as Cryptomeria in Japan. Within the past ten years, several countries have incorporated rooted cuttings into their regeneration program. Lower Saxony, West

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1 Dr. D.P Webb, Great Lakes For. Res. Centre, Sault Ste. Marie, Ontario

Germany has been able to produce one million rooted cuttings of Norway spruce (Picea abies (L.) Karst.) annually (Kleinschmit and Schmidt 1977). In this program, the cuttings were obtained from superior seedlings of selected provenances. The objective was to produce 30 to 40% of the total planting need with rooted cuttings. Juvenility of the selections was maintained through serial propagation and hedging. Several thousand rooted cuttings of Norway spruce have been planted annually in Finland. Their material originated from the best seedlings from their best families (Lepisto 1977). New Zealand planted tens of thousands of rooted cuttings of Monterey pine (Pinus radiata D. Don) (Libby 1976). Ontario has planted several thousand rooted cuttings of black spruce (bulk seedlot origin) and will be enlarging its program substantially within the next year or two. Finally, an Eucalyptus program in Brazil has recently started to use rooted cuttings on a large scale in its operational plantings (Zobel pers. comm. 1981).

The advantages of using rooted cuttings in production plantations are many, and chief among them is the greater gain than with conventional seedling plantations. With the seedling approach, the breeder is able to utilize only a portion of the genetic variance, while with rooted cuttings, the breeder may capitalize on all of the genetic variance. Rooted cuttings can also allow capture of more of the additive genetic variance within families, which makes the breeding program more effective (Libby 1977).

Uniformity of product is another advantage of regeneration with rooted cuttings, making operations more simple and efficient for both raw material consumers and forest managers. Uniformity of clones can also allow a fine tuning of specific clones to specific sites to a much greater degree than is possible using open-pollinted families from seed orchards.

Regeneration with rooted cuttings can alleviate some of the problems of large fluctuations in the periodicity of cone crops. In Ontario, good seed crops occur in black spruce and tamarack infrequently. Even with extensive management, it is expected that this periodicity will occur to some extent in seed orchards as well. In order to cope with the seed shortages, plans call for the clonal reproduction of seedlings. Obtaining regeneration stock from cutting orchards would alleviate the problem of seed shortages and provide sufficient stock to fulfill regeneration targets.

Interspecific hybrids are difficult to produce on a mass production basis. Either inefficient open-pollinated orchards or expenseive large control-pollination programs are necessary. Rooted cuttings are an obvious solution to this problem (Duffield 1981). The most successful hybridization program to date in forestry has been with poplars, and there, vegetative propagation is the rule rather than the exception. In Ontario, the interspecific hybrid spruce program is being de-emphasized, but a few promising combinations are being considered for vegetative propagation. Approximately 4,000 rooted cuttings from 33 clones of a Picea rubens Sarg. x Picea omorika (Panic) Purkyne hybrid

will be planted in a prodution trial in 1982[1].

Finally, the use of rooted cuttings for regeneration can reduce the period between test results and planting improved stock (Libby 1969, Zobel, 1981). By keeping some ramets of a clone hedged in a cutting orchard while other ramets are being field tested, many cuttings can be produced as soon as superior clones are identified. Thus the period between results and full production will be less than the corresponding period in a seed orchard program.

## CONCERNS WITH USING ROOTED CUTTINGS

We have described in the above sections the many advantages of using rooted cuttings in various phases of tree improvement. However, as with most frontiers and changes in technologies, there are some concerns. For many of the advantages discussed above, we assume that rooted cuttings will grow better than or at least as well as seedlings. In some coniferous species this assumption is still questionable. We further must assume that if rooted cuttings cannot be produced as cheaply as seedlings, then the gain in product and economies of management will more than offset the higher production costs.

Another concern often expressed about clonal plantings is the fear of monoculture, and the potential for disaster with genetic uniformity. Libby (1981) recommended from 7 to 30 as a safe number of clones in a given production plantation, the exact number depending on several variables such as acceptable risk levels, intensity of management, plantation size, and rotation age. Further, a mosaic of clones, rather than a mixture of clones, was recommended as a management system that may even have advantages in pest resistance over conventional plantations of open-pollinated families with their mixtures of full- and half-sibs (Libby 1981, Zobel, 1981).

In genetic tests a disadvantage of clones is the loss of selection differential, given that the number of trees that can be planted and measured has an upper limit. A further problem is the bias, associated with genetic parameters, arising from common environmental effects ("C" effects).

## PROBLEMS THAT STILL NEED SOLUTIONS

Since, for a large number of our important tree species, only juvenile material roots easily and grows well, maintaining this physiological condition is a necessity. Hedging and repropagation have been used to retard, but not halt, maturation. An expected benefit of tissue culture research will be a method to effectively rejuvenate mature tissue.

Technological development is needed to produce a management

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[1] Material obtained from Dr. A.G. Gordon, Ont. Min. Nat. Res.

system, with associated equipment, for large scale collection and rooting of cuttings.

## POTENTIAL IMPACT ON TREE IMPROVEMENT PROGRAMS

If rooted cuttings are used to any extent in the various areas described in this paper, a totally different look must be taken at conventional breeding strategies and approaches to breeding programs. For example, if the production plantations utilize rooted cuttings, production seed orchards can be phased out and replaced with smaller, more genetically diverse breeding and cutting orchards. It will be much cheaper to manage a clonal cutting orchard than extensive acres of production seed orchard. Since we are able to capture the best genotypes through vegetative propagation, yield per unit of time should be substantially superior to that produced from even good qualtiy seedling stock.

Although there are still some problems to be resolved, there is great potential in using rooted cuttings. For some species and some programs, this potential can be realized immediately. The challenge is ours to take advantage of what is known and to transmit this knowledge into practice.

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# EARLY FLOWERING AND SEED PRODUCTION POTENTIAL IN JACK PINE SEEDLING SEED ORCHARDS

Thomas D. Rudolph

*Principal Plant Geneticist*

*USDA, Forest Service*

*North Central Forest Experiment Station*

*Forestry Sciences Laboratory,*

*Rhinelander, Wisconsin*

## ABSTRACT

Jack pine improvement programs, whose ultimate goals are to produce high quality, genetically improved seed in seed orchards, are underway throughout much of the commerical range of jack pine in Canada and the United States. Information is presented on the early seed production potential needed for planning, establishing and managing such orchards. Seedling rather than clonal orchards are recommended primarily because clonal orchards cost more to establish and produce less seed. Cost of establishing and managing seedling orchards is low and generations can be turned over rapidly in breeding populations to create improved trees for subsequent orchards. Significant amounts of seeds are produced by age 6 and within the first 8 years 2.9 million filled seed per hectare of orchard can be produced. Costs of thinning and other cultural treatments to prolong orchard life beyond 10 years of seed production probably cannot be justified because additional genetic gains can be made by proceeding to new orchards based on progeny tests and breeding done in the interim. Seed losses due to abortion, insects, and squirrels continue to be problems that need more research. As these problems are solved and cultural and hormone treatments are further improved resulting in even earlier and more prolific seed production, we can expect that useful life of a given generation jack pine seedling seed orchard will be even shorter. Future seedling seed orchards should be located for maximum production of high quality, genetically improved seed, perhaps south of the natural range of the species.

## RÉSUMÉ

Dans la plus grande partie de l'aire d'exploitation du pin gris au Canada et aux États-Unis, des programmes d'amélioration de cette espèce sont en oeuvre, et leur objectif est d'arriver à produire, dans des vergers, des graines de haute qualité, génétiquement améliorées. On présente de l'information concernant les possibilités de production

précoce de graines, information utile pour la planification, la mise sur pied et la gestion des vergers de ce genre. On recommande des vergers à graines de familles plutôt que des vergers de clones, principalement parce que ces derniers sont plus coûteux à mettre sur pied et qu'ils produisent moins de graines. Le coût d'établissement et de gestion de vergers à graines de familles est faible, et les générations qu'ils produisent peuvent être rapidement transformées en populations reproductrices d'arbres améliorés qui seront utilisés à leur tour pour d'autres vergers. Les sujets de 6 ans produisent déjà un nombre important de graines et, dans les huit premières années d'exploitation, un verger peut produire 2,9 millions de graines pleines par hectare. On ne peut probablement pas justifier les coûts des éclaircies et des autres traitements sylvicoles destinés à prolonger la production de graines du verger au-delà de 10 ans parce qu'on aura pu obtenir entre-temps des améliorations génétiques supplémentaires en mettant sur peid d'autres vergers à partir de tests de descendance et de croisements. Les pertes de graines dues à des avortements, aux insectes et aux écureuils sont toujours des problèmes et appellent encore de la recherche. À mesure que ces problèmes seront résolus, que les traitements sylvicoles et aux hormones seront améliorés et qu'on obtiendra ainsi une production de graines plus précoce et plus abondante, on peut s'attendre à ce que la vie utile d'un verger à graines de familles de pins gris sera de plus en plus courte. Pour une productin maximale de graines de haute qualité génétiquement amélioreés, les futurs vergers devraient peut-être être établis au sud du domaine naturel de l'espèce.

## INTRODUCTION

Jack pine (Pinus banksiana Lamb.) improvement programs are underway throughout much of the commercial range of jack pine in Canada and the United States (Rudolph and Yeatman 1982) and vary widely in extent, intensity, and investment. Examples of extensive programs to produce large quantities of improved seed, required primarily for direct seeding, are the seed production stands developed near Baskatong Lake in Western Quebec (Lamontagne 1980) and in the Gogama District in Central Ontario (Oldford et al. 1979). Among more intensive improvement programs is one begun in the Lake States that combines both short- and long-term breeding and improvement objectives and is based on the Coordinated Population Concept (Kang 1980). The base population selected within a breeding zone is randomly divided into subsets of index or research populations and breeding populations, which will be used to develop production populations or seed orchards.

All of these programs are based on the best available provenance test information for delineating breeding zones and seed zones. The research results obtained from the index populations in the Lake States program will be used to predict the average performance of the breeding populations and to develop general breeding prescriptions for subsequent generations. Emphasis in the index populations is on rapid generation turnover so that various breeding schemes, selection methods, and other breeding activities may be evaluated as quickly as

possible. Advantage is taken of rapid generation turnover based on evidence that age-age correlations for growth, although not exceptionally high when young ages are involved, are sufficient to assure selection of most "winners" by age 5 (Lambeth 1980; Rudolph and Yeatman 1982). These evaluations will provide opportunities for manipulating the breeding populations to develop production populations or seed orchards for mass producing genetically improved seeds to meet regeneration needs within the breeding or seed zone.

All jack pine improvement programs, whose ultimate goals are to produce high quality seed in seed orchards, need information on the early seed production potential of seed orchards. Although information is limited on seed production from the few currently producing seed orchards, scattered information from other research provides some insight on what might be expected from future orchards. Here I will bring together information on early flowering and seed production that will be useful for planning, establishing, and managing jack pine seed orchards. We need to recognize that a given improvement program may have more than one type of population or orchard managed for different purposes. Breeding and research populations, for example, would be managed as progeny tests and to facilitate controlled breeding and not necessarily for mass producing seed. However, after seedlings for the next generation seed orchard have been produced by breeding of the selected trees, the breeding population may be used as an interim seed source in the early stages of a multi-generation, long term improvement program. A production population or orchard, on the other hand, would be managed for producing large quantities of high quality seed in the shortest possible time. Thus, because the purposes of breeding and seed production populations are different, it is important that they be considered as separate functions in an improvement program. The information presented here will be useful for managing both breeding and production populations but emphasis is on seed production populations or orchards.

## WHY SEEDLING SEED ORCHARDS IN JACK PINE?

Jack pine has numerous characteristics that favor the seedling rather than the clonal seed orchard approach (Wright 1964). It frequently occurs over large areas in relatively pure, even-aged stands that lend themselves well to selection of large numbers of trees at low cost (Rauter 1980). Candidate trees can be compared with many trees growing in the immediate vicinity so that differences due to site can be minimized. Current information, although not definitive, suggests that phenotypic selection for height growth may not be very effective in jack pine (Canavera 1975) so large investments in selecting superior trees in natural stands probably cannot be justified because the expected gains from such selection are small. Thus, a low selection differential should be used but, because of the low cost of selection, a large number of trees can be included in an improvement program.

The seedling seed orchard approach in jack pine improvement is further enhanced because the species has rapid early growth, normally produces seeds at young age, flowers consistently year after year, and

usually has serotinous cones so seeds may be temporarily stored on the trees if necessary (Rudolph 1979b, Yeatman 1979, Rudolph and Yeatman 1982). Thus, the small number of cones produced in the first several years in an orchard can be held on the trees until total production makes collection economically feasible.

Grafting is the only practical method at present to establish clonal orchards of jack pine from selections made in natural stands. However, grafted jack pine trees have several disadvantages compared to seedlings: (1) they are slow to develop large, cone-bearing crowns, (2) they cost more, and (3) graft incompatibility may eliminate some genotypes entirely (Rudolph and Yeatman 1982).

Clonal orchards may have a place in subsequent generation orchards based on the results of progeny tests. However, the higher costs of clonal orchards may outweigh the small additional short-term interim gains these orchards may make possible compared to selection and improvement facilitated by rapid turn over of seedling generations.

The early flowering and seed production results discussed below support the seedling seed orchard approach and indicate the rate of progress that can be anticipated in proceeding to advanced generation seed orchards.

## EARLY FLOWERING AND SEED PRODUCTION POTENTIAL

Under favorable growing conditions in the greenhouse and nursery, a small percentage of jack pine seedlings can be induced to produce female strobili as early as 12 months from seed (Rudolph 1979a). In other populations under these conditions, the percentage of trees producing female strobili increased to 23 percent at 17 months and 62 percent at 23 months (Table 1). The average number of strobili per tree ranges from one to two and they are usually borne on the main stem. The percentage of strobili maturing into cones and the number of filled seeds per cone are reduced, probably due to the lack of pollen production at this age (Rudolph 1966). However, controlled pollinations on the young seedlings resulted in cone set and filled seed percentages similar to pollinations on older trees.

An average of 17 percent of trees from various Lake State provenances grown in a nursery near Rhinelander, Wisconsin, flowered at 17 months (Table 2) (Jeffers and Nienstaedt 1972). Differences among provenances in proportion of trees flowering were small on the average and ranged up to 30 percent. Thus, although some differences in age for initiation of first flowering are evident among Lake State provenances, they are minor and probably of little significance when combining selections from this broad breeding zone into a coordinated base population for an improvement program.

Table 1. Female flowering and seed production on 17- and 23-month-old jack pine seedlings (adapted from Rudolph 1966)

| Seedling age | % of trees with female strobili | No. of female strobili per tree | % of cones maturing | Ave. No. seeds per cone | % seed germination |
|---|---|---|---|---|---|
| 17 Months | 23 | 1.34 | 10 | 25.9 | 36 |
| 23 Months | 62 | 2.08 | 50 | 26.4 | 77 |

A major hindrance in taking advantage of such early female flowering is from the 3 to 4 year lag in male strobili production. Pollen production is probably not adequte for complete pollinations until the fifth or sixth year (Rudolph 1966, 1979a,b, 1981). A low cost supplemental pollination using artificially applied pollen from other selected trees could be considered to increase cone set and filled seed production in jack pine orchards younger than 6 years.

Table 2. Female strobili production on 17-month-old jack pine seedlings by provenance of female parent (adapted from Jeffers and Nienstaedt 1972)

| Provenance | % trees with female strobili | No. females per flowering seedling |
|---|---|---|
| Cass Co., MN | 17 | 1.16 |
| Forest Co., WI | 18 | 1.14 |
| Manistee Co., MI | 16 | 1.13 |
| Douglas Co., WI | 19 | 1.14 |
| Marinette Co., WI | 14 | 1.21 |
| Wood Co., WI | 12 | 1.19 |
| Mean | 17 | 1.15 |

Jeffers (1976) projected seed yields in a hypothetical seedling seed orchard at age 6 years based on actual seed production in a 5-year nursery test. His orchard was designed to permit heavy rogueing. In this scheme, families would be planted in replicates of 2- to 4-tree row plots with a 0.5 m spacing between trees within rows and a 2.5 m spacing between rows. The seed orchard would initially contain 8,000 trees per hectare. The first thinning, (probably no later than the fourth year) would be based on performance measurements and would remove more than half of the trees and retain 3,200 trees per hectare. Based on female strobili counts in the fifth year and assuming 50 percent loss of strobili before cone maturity and 25 filled seeds per cone, he projected production of 266,800 filled seeds per hectare in the sixth year. Assuming 80 percent of the filled seed would yield plantable seedlings, 213,400 seedlings could be produced per hectare of orchard.

Using a somewhat different approach to orchard establishment than that of Jeffers, Rudolph (1979b) determined actual cone and seed production in the first 6 years in a seedling seed orchard (Table 3). The planting was established from a single local stand seed collection and was typical of a seed orchard scheme in which no rogueing or thinning would be done in the first 10 years. Thus, no selection was imposed and the overall quality of the trees was undoubtedly lower than in Jeffers' seed orchard in which more than 50 percent of the poorer families and trees were rogued. Therefore, one might expect early seed production to also be lower than in Jeffers' orchard, assuming that faster growing trees have higher early seed production. Greenhouse and nursery culture of the two orchard populations were similar and the field plantings were in the same general area but Rudolph's orchard was at a much wider spacing (2.44 m x 2.44 m) resulting in about one-half as many trees (1,683) per hectare.

Table 3. Mature cone and seed production of jack pine trees 4, 5, and 6 years old from seed (adapted from Rudolph 1979b)

| Age | % of trees with cones | No. Cones per tree | No. Seeds per tree | No. filled seed per tree | % of seed filled | No. filled seeds per hectare at 2.44 x 2.44 m spacing |
|---|---|---|---|---|---|---|
| 4 | 16 | 0.3 | 2.8 | 0.6 | 23 | 1,085 |
| 5 | 47 | 1.1 | 11.6 | 8.0 | 69 | 13,415 |
| 6 | 93 | 10.1 | 221.2 | 166.7 | 75 | 280,491 |
| Total filled seed per hectare produced in first 6 years - | | | | | | 294,991 |

Contrary to what was expected, the actual yield of filled seed per hectare in the sixth year in Rudolph's orchard was slightly higher (280,000) than the projection (267,000) in Jeffers' orchard. The difference in spacing between trees in the two orchards would probably not yet be an influencing factor on early seed production because even at the narrower spacing in Jeffers' orchard, crown competition would not have occurred.

Adding the number of seeds produced in the fourth and fifth year in Rudolph's orchard to those of the sixth year gives a total of 295,000 filled seeds per hectare and, assuming that 80 percent would produce plantable seedlings, 236,000 seedlings. Noteworthy is the increase from less than one-fourth of the seed being filled in the fourth year to three-fourths in the sixth year. This is likely due to the increase in pollen production after the fourth year noted earlier.

Cone production data are not available for Rudolph's (1979b) orchard in the seventh year. However, conelets on the trees in midsummer of the seventh year were counted to project seed production in the eighth year (Table 4). An average of about 43 conelets per tree were produced. Allowing for 10 percent additional cone loss in the second year of cone maturation and assuming 25 filled seeds per cone, 1,619,000 filled seeds per hectare would be produced. Assuming production in the seventh year would be midway between the sixth and eighth year, 950,000 filled seeds per hectare would be expected. The actual production for the first 6 years (Table 3) plus that projected for the seventh and eighth years (Table 4) results in 2,863,000 filled seed per hectare produced in the first 8 years. If 80 percent of the filled seed produces plantable seedlings, 2,290,000 seedlings per hectare of seed orchard can be produced within the first 8 years from about 1,700 trees.

Although information on seed production in the above-described orchard after the eighth year is not available, general observation indicated that cone production continued to increase rapidly for the next several years until crown closure became a limiting factor. At that time, thinning may be necessary to keep the crowns in the open if the orchard was to be continued. Removing the top two to three "whorls" of crown would also help keep the height at which cones are produced within more easily collectible reach. Considering the production of 1.65 million filled seeds per hectare in the eighth year, subsequent annual production could be expected to be more than 2 million -- yields that should make management of seed orchards for early seed production worthwhile.

However, the cost of thinning and other cultural treatments to prolong the life of the orchard may not be justifiable because of the low cost of establishing and managing such a jack pine orchard in which the only treatments were to prepare the site with a herbicide and mow between rows for the first 2 years. Instead, considering the opportunities by the time an orchard is 10 years old of advancing to the next generation orchards because of rapid generation turnover in the breeding population in the interim, investments should be made in new orchards with the

objective of achieving additional gains. Seedlings for the new orchards would be selected based on the early performance of controlled breeding progenies from the progeny test breeding population. The costs of using this approach for the continuing production of genetically improved seed will add little to the total cost of artificial regeneration and plantation management to tree harvest, and the gains to be achieved can be expected to yield a good return on the investment (Lundgren and King 1965, Carlisle and Teich 1975).

Table 4. Seed production in the first 8 years in a jack pine seedling seed orchard at a 2.44 x 2.44 m spacing (adapted from Rudloph 1979b)

| | |
|---|---|
| Total filled seed production per hectare through age 6 | 294,991 |
| Average number of conelets per tree in summer of seventh year | 42.75 |
| Number of cones per tree maturing in eighth year assuming additional 10 percent cone loss | 38.48 |
| Number of cones per hectare in eighth year at 2.44 x 2.44 m spacing (1,683 trees) | 64,753 |
| Number of filled seeds per tree in eighth year assuming 25 filled seeds per cone | 962 |
| Number of filled seed per hectare in eighth year at 2.44 x 2.44 m spacing (1,683 trees) | 1,618,806 |
| Number of filled seed per hectare in seventh year assuming mid-point bewtween sixth and eighth year | 949,647 |
| Total filled seed production per hectare through age 8 | 2,863,444 |

## LOCATING ORCHARDS FOR BEST SEED PRODUCTION

As soon as results from progeny tests made in the breeding zone are available, and seedlings for the next generation orchards are produced by controlled pollination on selected trees in the breeding population, seed orchards should be located for maximizing seed production and quality, possibly outside the breeding zone.

Seed yield per cone and seed quality from trees in 15 provenances at 5 plantation locations showed striking differences due to plantation location (Rudolph and Cecich 1979). Trees in a plantation at Plattsmouth, Nebraska, which is far south of the natural range of jack pine, produced more filled seeds per cone and more plantable seedlings

per cone than trees of the same provenances in four Lake States plantings (Table 5). More than three times as many filled seeds per cone were produced in Nebraska as in a planting at Black River Falls, Wisconsin, which is within the natural jack pine range. The planting at Black River Falls is apparently on a poor site although natural jack pine stands are found there. Another planting on a better jack pine site, at Lake Tomahawk in northern Wisconsin approached the seed yield and quality of the Nebraska planting. These results, although preliminary, suggest that seed orchard site selection for maximum production of high quality seed must be carefully considered and that location of orchards outside of the breeding or seed zone and south of the natural range of jack pine in longer growing season areas cannot be dismissed. Additional research on optimum seed orchard location for early and high seed production in jack pine is now underway by the North central Tree Improvement Committee (NC-99) (Nienstaedt 1981).

Table 5. Seed yield and seed characteristics of trees in 15 provenances at 5 plantation locations (adapted from Rudolph and Cecich 1979)

| | | Cone and seed characteristics[1] | | | |
|---|---|---|---|---|---|
| Plantation location | No. trees | No. seeds per cone | No. seeds per cone | % seeds filled | % total seed germination |
| Plattsmouth, NB | 88 | 33.4 | 23.9 | 70 | 67 |
| Kellogg Forest, MI | 72 | 20.6 | 10.3 | 46 | 43 |
| Black River Falls,WI | 100 | 20.6 | 7.0 | 33 | 31 |
| Lake Tomahawk, WI | 144 | 24.2 | 21.3 | 88 | 85 |
| Grand Rapids, MN | 70 | 21.8 | 18.4 | 84 | 82 |
| TOTAL | 474 | | | | |
| MEAN | | 24.2 | 16.7 | 66 | 63 |

[1] Differences among locations are significant at the 1 percent level for all characteristics.

## PROBLEMS IN ORCHARD MANAGEMENT FOR EARLY SEED PRODUCTION

Design and spacing are major concerns when establishing seedlings seed orchards (Rauter 1980). Many different designs, spacings, and rogueing approaches have been proposed (see review in Rudolph and

Yeatman 1982). Designs will vary with total orchard size and shape, the number of genotypes, whether rogueing will be done, and the selection method used in rogueing. All designs should include random placement of trees or families in replicated blocks.

In seedling seed orchards containing material that has already been progeny tested and no further rogueing or thinning is planned for at least 10 years, spacing for maximum seed production during the period should be 2.5 m x 2.5 m to avoid crown closure and competition and to maximize potential cone producing crown surface. If rogueing is planned at age 4 or 5, row plots of no more than four trees per plot should be used. Spacing between trees within rows can be close initially, e.g., 1.5 m, to allow for the rogueing. Spacing between rows should be 2.5 m, so grasses and herbaceous vegetation can be mowed for the first several years.

Cone abortion continues to be a serious problem (Cecich 1979) and its causes in young seed orchards are unknown. Seed yields in jack pine may be low in many instances due to low seed potential (2 x number of fertile scales) and resulting low seed efficiency (number of filled seeds/seed potential) (Bramlett 1974). It may be possible to increase seed yields in young orchards by selecting for high seed efficiency rather than high cone production (Polk 1966, Todhunter and Polk 1981).

Cone and seed insects cause serious losses in seed production on young jack pines (Rauf *et al*. 1981, Rudolph 1981). For example, the jack pine budworm (*Choristoneura pinus pinus* Freeman) destroyed 12 percent of the conelets in a planting in northeastern Wisconsin. A mirid (*Platylygus luridus* Reuter) was observed piercing into conelets as well as shoots and needles and was apparently responsible for severe but unknown conelet losses that may previously have been considered as abortion due to other causes. Numerous other insects are responsible for lesser amounts of damage (Rauf *et al*. 1981). Losses due to insects and abortion can reach more than 90 percent of a seed crop during heavy insect infestations (Rudolph 1981). Clearly, control of cone and seed insects and prevention of abortion in jack pine seedlings seed orchards are problems that must be solved if the early flowering and seed production potential is to be used to advantage.

Red squirrels (*Tamiasciurus hudsonicus* Allen) destroy cones and consume seeds (Rudolf 1965, Rudolph and Cecich 1979, Rudolph and Yeatman 1982). Losses to squirrels can be minimized by carefully timing cone collection so that cones are taken as soon as seeds are viable and before squirrels begin to harvest them (Cecich and Rudolph 1982). The following indicators of cone and seed ripeness proved to be best for northeast Wisconsin: 75 percent of the cone was brown, inside surfaces of the cone scales were reddish brown, seeds were dark brown or black, and cone moisture content was less tha 42 percent of fresh weight. These indicators of cone and seed ripeness coincided with the beginning of cone harvesting by squirrels (Cecich and Rudolph 1982).

Although most jack pine trees bear serotinous cones, some bear

cones that open soon after they mature resulting in potential seed losses in orchard production. Such losses may be most serious in young orchards in which the small cone crops are retaind on the trees for the first several years of production until the accumulated crop reaches levels that are economically feasible to collect. The serotinous cone character is highly heritable so selection for it can be effective (Rudolph et al. 1959, Teich 1970, Sittman and Tyson 1971). Therefore, if other tree characteristics of potential selections for orchards are equal, the serotinous cone habit should be favoured (Rudolph and Yeatman 1982). Straight cones also should be preferred for orchard selections because they yield more seeds than curved ones (Jeffers 1972, Baker 1980, Rudolph and Yeatman 1982).

## FUTURE PROSPECTS

The future is bright for obtaining earlier and higher production of genetically improved seed from jack pine seedling seed orchards than is presently possible. Although many problems remain to be solved, research advances are expected on the following fronts: (1) time to first flowering will be further shortened by cultural manipulation of photoperiod, temperature, moisture, and nutrients, particularly during the intial stages of seedling development; (2) flowering will be increased by effective hormone applications such as gibberellin $A_{4/7}$ (Cecich 1981); (3) economically feasible application methods will be developed whereby entire orchards can be treated; (4) methods of controlling cone and seed insects and other damaging agents will be improved; and (5) causes of conelet abscission and abortion will be identified and losses due to these causes will be prevented.

Because all of these developments permit an even more rapid generation turnover in jack pine breeding, opportunities will be provided for earlier evaluation of various breeding schemes, selection methods, age to age performance correlations, and other breeding activities. This points to a decreasing practical life for a given generation jack pine seedling seed orchard in the future. Clearly, a useful orchard life of no more than 10 years is in sight. One combined progeny test-seedling seed orchard established in 1974 by the Potlatch Corporation in north Central Minnesota will soon be phased out and the second generation orchard will be established (Schantz-Hansen 1981). Within 6 years of establishment, this orchard produced almost 7 kg of high quality seed from 1,700 trees. The nursery manager that grew the seedlings from the orchard seed noted that the seed was much larger than seed from natural stands used previously and that the performance of the seedlings in the nursery was better than that from any previous natural stand collections.

As additional demonstrations of gains are produced from other jack pine orchards, managers and administrators of reforestation programs will increasingly realize that the cost of producing gentically improved seed in orchards adds little to the total cost of reforestation and forest management until harvest. The potential for genetic gain in jack pine is present—it needs to be developed and applied in reforestation

programs.

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# ONE GENERATION OF LOBLOLLY PINE TREE IMPROVEMENT: RESULTS AND CHALLENGES

**John T. Talbert**

*Liaison Geneticist*

*Tree Improvement Cooperative*

*Dept. of Forestry, N.C. State University*

*Raleigh, N.C.*

## ABSTRACT

Intensive first generation tree improvement programs in the southern United States with loblolly pine (Pinus taeda L.) and slash pine (Pinus elliotti Engelm.) are reaching maturity. Yields from first generation seed orchards are now approaching the demand for improved seed. Genetic gains for height growth of loblolly pine in the N.C. State-Industry Pine Tree Improvement Cooperative appear to be remaining stable at about 3% through 12 years of age in progeny tests. Extrapolation to later ages through the use of yield tables shows that the impact of a 3% height increase on percent volume improvement depends upon stand age and management practices. Percentage cubic meter volume gains in unthinned plantations are greatest before the oneset of intense competition and mortality in the stand. Greatest percentage gains in cubic meter volume will result through shorter rotations or thinnings to salvage mortality.

Challenges and opportunities in first generation improvement programs do not end as breeding programs focus on second generation activities. Additional gains in the genetic quality of first generation planting stock may be realized through family block plantings, mass propagation of full sib families, and super intensive roguing of seed orchards based upon complete progeny test information. Small increments of gain can mean a large difference in profitability.

## RÉSUMÉ

On est en voie d'atteindre les objectifs des programmes intensifs entrepris dans le sud des États-Unis pour améliorer les arbres de la première génération dans le cas du pin à encens (Pinus taeda L.) et du pitchpin américan (Pinus elliotti Engelm.). Le rendement de la première génération d'arbres des vergers à graines suffira bientôt à la demande de graines améliorées. D'après les tests de descendance, le gain génétique de croissance en hauteur semble avoir été de 3% par année pour une arbre de 12 ans à la N.C. State-Industry Pine Tree Improvement Cooperative. Si à l'aide de tables de rendement on extrapole pour un arbre plus vieux, on voit que l'effet d'un gain de 3% en hauteur sur le pourcentage d'amélioration du volume dépend de l'âge du peuplement et

des methodes d'aménagement. En pourcentage, le gain de volume en mètres cubes dans les plantations non éclaircies est le plus élevé avant que la compétition et la mortalité ne commencent à se manifester dans le peuplement. Ce gain sera à son maximum si l'on diminue l'âge d'exploitabilité absolue ou si l'on éclaircit la plantation pour faire décroître la mortalité.

Il reste encore des défis à relever et des points à améliorer dans les programmes pour les arbres de la première génération même si l'on oriente les programmes de reproduction vers la deuxième génération. On peut encore améliorer la qualité génétique du matériel de reproduction de la première génération par la plantation de familles en blocs, par la sélection massale des fratries et en éliminant des vergers à graines tous les rebuts de sélection en se fondant sur les résultats complets des tests de descendance. Des gaines minimes peuvent être très profitables.

## INTRODUCTION

Intensive genetic improvement of forest trees began during the 1950's in a number of countries throughout the world. In North America, programs dealing with loblolly pine (Pinus taeda L.) and slash pine (Pinus elliotii Engelm.) have been particularly active, and have reached a stage where members of the three largest cooperative improvement programs in the southern United States are able to meet all or part of their annual planting needs with improved stock[1]. Initial activities with these species involved intensive selection of superior phenotypes in natural stands, followed by establishment of clonal seed orchards and extensive progeny testing. Major breeding efforts are rapidly turning to the second generation of improvement (Talbert 1979; van Buijtenen and Lowe 1979).

Most emphasis in the North Carolina State University-Industry Pine Tree Improvement Cooperative is on loblolly pine. The approach taken was one of superior tree selection within geographic regions. Each Cooperative member was originally responsible for selection of 20-30 trees in natural stands. Trees were selected for growth, stem straightness, pruning ability, wood density, crown and branch characteristices, and selections had to be free of any fusiform rust (Cronartium quercum Bech Mizobe f. sp. fusiforme) infection. Estimated selection intensities varied from about i = 1.89 (7 in 100 individuals saved) for volume to i = .97 (40 in 100 individuals saved) for fusiform rust resitance, where the disease is a problem (Porterfield, 1973). Trees selected for each orchard were progeny tested utilizing a factorial mating design, where 4 or 5 clones were chosen as testers and mated to

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[1] The three cooperatives are the Western Gulf Tree Improvement Program, Texas A & M University; Cooperative Forest Genetics Research Program, University of Florida, and the N.C. State University-Industry Pine Tree Improvement Cooperative.

the other trees in the orchard. An attempt was made to test each full sib family in two different environments in each of three years. A randomized complete block design has been used with families planted in ten tree row plots in each block. Included in each block are plots of one or more unimproved seedlots. The same tests serve as a base population for selection of second generation parents.

Breeding efforts for first generation loblolly pine selections are now complete, with the final tests scheduled for establishment in the field in 1983. Test measurement is currently a major activity in the Cooperative with over 750,000 individual trees measured each year. Tests are measured after four, eight and twelve growing seasons in the field. For some orchards we have considered progeny test information sufficiently complete (most tests 8 years or older) to rogue them to their final clonal composition. Developmental work in the breeding and testing phase of the Cooperative is now focused on second generation tree improvement.

First generation seed orchards in the Cooperative are reaching full productivity. Cone crops have been heavy three out of the last four years, (Table 1) and some organizations have enough seed in storage to meet their needs for several years. We anticipate a record cone crop in 1981.

Table 1. Seed yield for N. C. State Cooperative loblolly pine seed orchards for the past four years.

| Harvest Year | Kilograms of Seed | Potential Regeneration (ha.)[1] |
|---|---|---|
| 1977 | 22,500 | 220,000 |
| 1978 | 21,300 | 209,000 |
| 1979 | 25,100 | 246,000 |
| 1980 | 7,200 | 70,000 |

[1] Assumes a 2.4 x 2.4 m spacing, and 17,000 plantable seedlings per Kilogram of seed.

While most orchards have been genetically rogued, there is opportunity for a further increase in the genetic quality of seeds produced, especially as supplies of improved seed become plentiful and maximum production is no longer a constraint in orchard management. Most of the challenges we currently face in the genetic aspects of first generation tree improvement involve seed orchard practices to upgrade the genetic quality of seed.

The N.C. State Cooperative is at a turning point in both its applied and developmental phases. While much effort is now given to second-generation activities, a number of first generation tests are at least 12 years old, and some trends in the performance of improved stock

The N.C. State Cooperative is at a turning point in both its applied and developmental phases. While much effort is now given to second-generation activities, a number of first generation tests are at least 12 years old, and some trends in the performance of improved stock are beginning to emerge. The first generation program can be described by the gains which are being achieved, and by the challenges which we are encountering as orchards and genetic tests reach maturity.

## GAINS FROM ONE GENERATION OF TREE IMPROVEMENT

Gains from tree improvement activities ultimately reside in the improved productivity of forest lands. Determination of realized gains in productivity, especially those in yield per unit area, usually involve establishment of long-term studies with large block plots comparing improved and unimproved planting stock. Since in most programs selections for the next generation are made well before rotation age, breeding activities will have advanced to the second or third generation before realized gains from first generation orchards are accurately known. For planning purposes, however, economic and silvicultural decisions involving management of plantations from first generation stock must be made early in the program. Consequently, estimates of gain from tree improvment must often be made from studies not designed specifically for that purpose.

The N.C. State Cooperative's first generation genetic tests were established primarily for progeny testing and selection purposes. The row plots utilized do not permit direct comparisons of yield among families or between improved stock and unimproved check lots. However, many tests have now been measured at four, eight, and twelve years of age and trends are evident in the relative performance of improved and unimproved stock over time. Extrapolation results to rotation age indicates that tree improvement will have important implications for forest management.

Average percentage gains in height growth for first generation loblolly pine progeny compared to unimproved checks are shown in Table 2. Gain figures were computed by determining average gain for each loblolly pine seed orchard in the Cooperative, and then averaging across all orchards. Each orchard was treated as an independent estimate of gain. Percentage gains for any individual orchard may be biased to the extent that the tester mating system used does not represent what would be obtained with random mating in the seed orchard, and to the extent that the unimproved check does note accurately represent unimproved planting stock[1]. However, when averaged across a number of orchards, these effects should average out.

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[1] In the first generation, each Cooperator was responsible for furnishing his own unimproved check. We know that unimproved checks of Cooperators in the same area differ in their performance. effects should average out.

Table 2. Average percentage height gains for first generation loblolly pine seed orchard stock at different assessment ages[1]

| | Age | | |
|---|---|---|---|
| | 4 | 8 | 12 |
| Percent Gain[2] | 3.14 | 4.06 | 2.84 |
| Standard Error | .45 | .52 | 65 |
| Range | -2.18 to 7.54 | -.79 to 8.00 | -3.49 to 6.89 |
| No. Orchard | 33 | 30 | 16 |

[1] Gains are calculated as average performance of progeny test seedlings in comparison to improved check lots.

[2] Percent Gains at all ages are significanty greater than 0 ($p < .01$). Gains at different ages are not significantly different from each other.

Percent gain estimates for height appear to be remaining constant at 3-4% regardless of test measurement age (Table 2). Individual orchards differ widely in their performance, but combined gain figures are all significantly greater than 0 ($p < .01$) and are not significantly different from each other.

Interpretation of percentage gains in young tests, and extrapolation to later ages is a matter of some debate. Cannell (1978) has questioned estimates of gain in yield from selection because genotypes are selected for individual growth rate, often at very young ages before intense tree to tree competition begins, and not for their ability to produce more wood per unit of land. An alternative argument is that yield per unit area can be partitioned into components due to carrying capacity and growth rate (Lambeth 1978). Carrying capacity is defined as the total amount of biomass that can be produced by a unit of land in a period of time. In forestry terms, it can be expressed as the number of stems of a given size that can occur on a particular unit of land at a given plantation age once full stocking is reached. Changes in carrying capacity in agricultural crops (total biomass) as a result of genetic improvement are generally considered to be minimal (Evans 1980). A nursery bed study with loblolly pine could not detect any family variation in carrying capacity (Wearstler 1978). But, even if we assume that carrying capacity for a given site is not subject to genetic manipulation, yields can still be increased by improving growth rate, for which there is substantial genetic variation in nearly every tree species that has been studied (Wright 1976). Improvement in growth rate will result in more rapid stand development which can decrease the time until

the stand reaches a certain harvestable size, or result in more merchantable volume at a given rotation age, packed onto fewer stems because of mortality.

If one assumes the percentage gain figures for height shown in Table 1 will remain constant at about 3% over time, then gain from selection can be expressed as a change in site index, or the expected height of the dominant and co-dominant trees in a stand at a base age. For example, if site index for improved stock is 60 feet (18.3 meters) (base age 25), then an equivalent site index using improved stock from unrogued orchards would be 1.03 x 60 ft. = 61.8 ft. (18.8 m). If one further assumes that through selection we have improved growth rate (stand development) and not carrying capacity, then changes in yield resulting from tree improvement can be obtained through use of growth and yield models. These models predict yield based upon initial plant density, site index, and plantation age or dominant tree height.

Predicted cubic meter volume yields in unthinned plantations for unrogued and rogued first generation loblolly pine seed orchards at various ages on site index $60_{(25)}$ land are shown in Table 3. Unrogued orchard stock was assumed to grow 3% faster in height than unimproved stock, changing site quality to an equivalent of site index $61.8_{(25)}$. Stock from rouged orchards was estimated from progeny tests to grow 7% faster in height than unimproved stock changing site index to an equivalent of $64.2_{(25)}$ (site index figures were rounded to 62 and 64 respectively). If an orchard were rogued strictly on height, estimated gains would be greater than 7%. In reality orchards are rogued on a number of characteristics, including cone production, which reduces effective selection intensity for height. The 7% figure is probably realistic for many orchards.

Predicted percentage gains in cubic meter volume decline dramatically with increasing age in the unthinned stand depicted in Table 3 (Figure 1). Gains for rogued orchard stock fall from 20% at age 15 to just under 5% at age 35. At age 25, a common rotation age on land of this site quality, percentage gains in cubic foot volume are 6.4% for plantations from unrogued orchards and 12.7% from rogued orchards, with no salvage of lost mortality by thinning. Absolute gains in volume appear to be remaining nearly constant with time after a plateau is reached at about age 20 (Table 3).

One of the reasons for decreasing percentage gains in volume is an increasing volume figure on which the percentage is based (Table 3). Examination of the stand data shows that another reason is increased mortality in stands planted with seed orchard stock, because of more intense tree to tree competition resulting from more rapid stand development. When the trees are in a "free to grow" situation, there is little mortality and percent improvement in cubic meter volume resulting from small changes in site index are large. Gains fall as competition sets in, more quickly on the better sites, and mortality begins to occur. Much of the loss in percentage gain can be recaptured if mortality is

salvaged by thinning.

Table 3. Stand densities and cubic meter volumes in unthinned loblolly pine plantation for site index 60, 62 and $64_{(25)}$ at various ages[1].

| | Site Index[2] | | | | | |
|---|---|---|---|---|---|---|
| | 60 ft. | | 62 ft. | | 64 ft. | |
| Age | Trees/ha. | $m.^3/ha$ | Trees /ha. | $m.^3/ha.$ | Trees/ha. | $m.^3/ha$ |
| 1 | 1480 | — | 1480 | — | 1480 | — |
| 15 | 1462 | 105.4 | 1457 | 116.1 | 1447 | 126.7 |
| 20 | 1380 | 206.4 | 1356 | 224.2 | 1329 | 241.4 |
| 25 | 1218 | 307.1 | 1178 | 326.8 | 1139 | 346.1 |
| 30 | 1015 | 359.6 | 973 | 378.3 | 909 | 398.1 |
| 35 | 830 | 392.7 | 790 | 402.8 | 758 | 410.4 |

[1] Differences in yield for small changes in site index were calculated utilizing models developed by W.L. Halfey and W.D. Smith, Southern Forest Research Centre, Department of Forestry, N.C. State University (as yet unpublished). I gratefully acknowledge their assistance.

[2] site index $60_{(25)}$ = unimproved stock
site index $62_{(25)}$ = unrogued orchard stock
site index $64_{(25)}$ = rogued orchard stock
All volumes are total tree inside bark.

Changes in percent volume gains with increasing stand age have important implications for forest management. If the best potential percentage gains from tree improvement are to be realized, stands must either be harvested before intense competition and associated mortality begin, or stands must be thinned to salvage mortality. In stands that are to be thinned operationally, the time of first thinning will come at a younger age when improved stock is used (Switzer and Shelton 1981).

Gains in volume production from genetics can be utilized by the forest manager in two ways. One would be to harvest timber when it reaches a given size, and genetic improvement would be realized as a

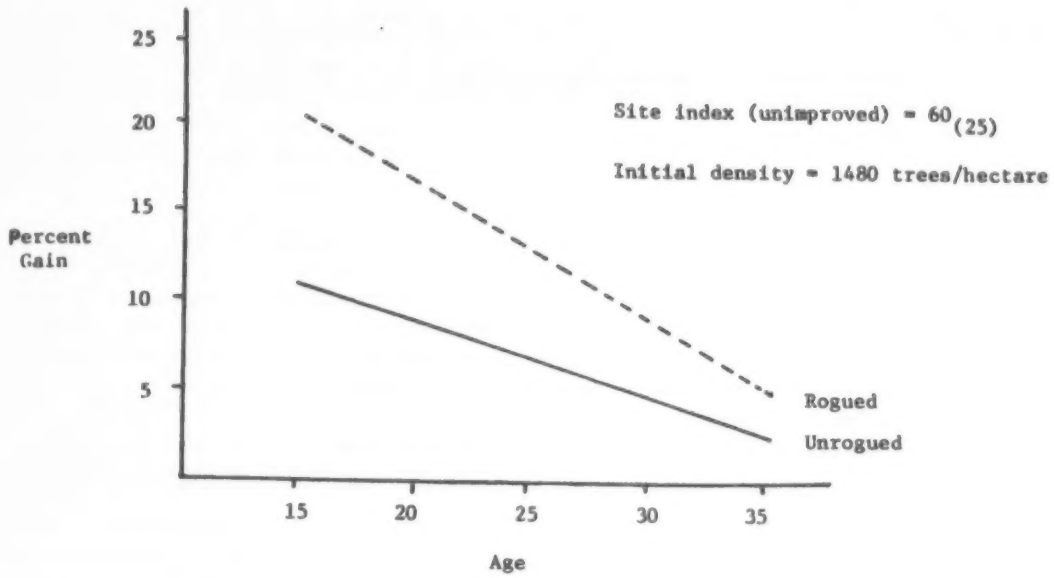


Fig. 1. Influence of age on percentage cubic meter volume gain in unthinned loblolly pine plantations utilizing first generation orchard stock.

reduction in rotation age. If this were the case, and rotation length for unimproved stock on site index $60_{(25)}$ land were 25 years, then use of periodic annual increments generated from Table 3 would show that rotation could be reduced to 24 years with unrogued orchard stock, or to 23 years with rogued orchard stock. Gains in cubic meters of wood from tree improvement would simply be 4.1% (25/24-1) for unrogued orchards, and 8.6% for rogued orchards. A reduction in rotation age can substantially improve profitability by decreasing the number of years that plantation establishment costs must be carried (Lambeth 1978).

Alternatively, the manager could decide to grow the stand for the same rotation length, and enjoy the benefit of harvesting more volume per acre, concentrated on fewer but larger, more valuable stems. Gains in estimated dollar value for 25 year rotation on site index $60_{(25)}$ land with this alternative are shown in Table 4. Unrogued orchards yield an 18% increase in dollar value at age 25, while a 32% increase in value results from use of stock from rogued orchards, given the assumptions listed in Table 4. The large increases in value associated with small gains in cubic meter volume are the result of more trees in the larger diameter classes.

Table 4. Improvements in value in unthinned plantations at stand age 25 utilizing unrogued and rogued seed orchard seed on site index $60_{(25)}$ land.

| Type Stock | Value (Dollars/ha.) | % Gain |
|---|---|---|
| Unimproved | 4152 | -- |
| Unrogued | 4891 | 18% |
| Rogued | 5476 | 32% |

Assumptions:

Value of trees < 23 cm dbh = $12/cord
Value of trees 23-31 cm dbh = $40/cord
Value of trees 31+ cm dbh = $60/cord
1 cord = 2.56 cubic meters of solid wood

Increases in stumpage values shown in Table 4 are probably conservative. Growth rate was the only trait considered, and improvment in quality characteristics have been ignored. Test data shows that genetic improvements in quality have been large, especially in stem straightness, and that variation in these characteristics have a marked impact on yield of both solid wood and pulpwood products (Blair et al 1974). The improvements in quality undoubtedly have an impact, especially in stands harvested at young ages where quality characteristics play a large role in determining whether a log is of pulpwood quality or whether it could be used for solid wood products. Research is currently underway to more fully elucidate the relationship between the crown and straightness scores used in N.C. State Cooperative and product yeild.

Genetic gains have also been made in other characteristics. Wood specific gravity is a highly heritable trait in many species, including loblolly pine (Otegbye and Kellison 1980; Dadswell et al 1961; van Buijtenen 1965; Zobel et al 1972). Based upon parent-offspring correlations, we have estimated that with one generation of light selection for increased wood specific gravity (1 in 2 individuals saved), improvement has been on the order of 9.6 kilograms per cubic meter of dry wood in 12 year-old trees (Jett and Talbert 1980).

Improvements in fusiform rust resistance appear to be resulting largely from progeny testing and orchard roguing. There is considerable genetic variation in fusiform rust resistance in loblolly pine (Kinloch and Stonecypher 1969). In progeny tests, however, unimproved check lots have performed nearly as well, on the average, as progeny of selected trees. This has happened even though a requirement for first generation

selections was that they be free of rust. Many selections were made in stands with low to intermediate rust infection, so there was a low selection intensity for disease-free trees. It has been shown that substantial gain can be made in rust resistance in slash pine by selecting rust-free trees in heavily infected stands (Goddard and Schmidt 1979). Where fusiform rust resistance is of over-riding importance, specialty loblolly pine seed orchards composed of proven rust-resistant parents have been established (Zobel et al 1971).

There is no longer any doubt that substantial genetic gains can be made in forest trees in one generation of selection. Changes in the genetic composition of the forest stand will have a large impact on forest management strategies (Zobel 1979). It is important that the tree breeder and forest manager realize that gain figures for volume, stem straightness, or any other characteristic must be interpreted in relation to their effects on stand development and associated management activities. Gains for any trait, expressed in biological or economic terms, can and will change dramatically during the life of the stand, and with different management practices.

## CHALLENGES IN FIRST GENERATION LOBLOLLY PINE TREE IMPROVEMENT

Although substantial gains have been made in one generation of selection, progeny testing, and orchard roguing, there are opportunities for further increases in productivity of first generation planting stock. These arise primarily because of two factors. First, an excellent data base exists for performance of both half and full sib families in progeny tests that were established for first generation orchards. Second, seed production in orchards has exceeded expectations, and several seed orchards are now producing quantities of seed far in excess of what is needed for regeneration purposes for the organization involved. Some opportunities can be taken advantage of almost immediately; others are very much in the experimental arena.

### Planting by Half Sib Family

Progeny tests have shown that seed orchard parents differ widely in general combining abilities. This information has been used extensively to rogue seed orchards, but the genetic quality of seed can be improved further by collection of seed only from those parents which have the highest combining abilities. Orchard clones can be divided into groups according to the gain that will be obtained from their use. For example, families which have shown excellent resistance to fusiform rust could be collected separately and used in areas of high rust incidence. Taken one step further, seed collection could be kept separate by clone, and sown in the nursery and planted in the field in a similar manner. An immediate benefit of this practice is increased seedling quality and uniformity in the nursery; another is that half-sib families can be planted and managed for their most appropriate end product. One organization has been planting in half-sib family blocks for several years (Gladstone 1981). With the record cone crop anticipated in 1981, we expect several companies to collect cones by clone or groups of clones

this fall.

Mass Production of Full Sib Families

In almost every testing program, occasional full sib families prove to be excellent performers in every important characteristic. An example of one such family is shown in Table 5. The use of several fully progeny tested families like 1-11 x 5-33 in a regeneration program would result in excellent improvements in growth, form, and rust resistance. Use of some specific crosses would result in estimated height gains of 25% or more. Mass production of full-sibs through control-pollinations is not economical, but several technological developments on the horizon may lend themselves to production efforts.

One possibility for production of full-sib planting stock is two-clone seed orchards. However, there are problems with establishment and management of two-clone orchards. The two clones must be similar in phenology (flowering time) so that cross-pollination will occur in the orchard. Additionally, at least one of the two clones must either not produce filled seed upon selfing, or must produce selfed seed of good genetic quality. Several two-clone orchards have been established, but they have yet to become productive and their ultimate utility is unknown.

Table 5. Performance of family 1-11 x 5-33: A case for mass propagation of full siblings.

| | Trait | | | |
|---|---|---|---|---|
| | Height | Volume | Form | Fusiform Rust Resistance |
| Performance Level[1] | 76 | 71 | 72 | 87 |
| Rank (out of 83) | 4 | 7 | 19 | 1 |

[1] Performance levels are calculated on a 0-100 basis; 50 is approximately average.

A more likely alternative for mass production of full siblings, at least in the near future, is through supplemental mass production (SMP). Results to date with SMP have been variable. An attempt to mass produce the hybrid pitch pine (Pinus rigida Mill.) x loblolly pine produced an average of 10.7% hybrid seedlings (Bridgwater and Trew 1981). In a study designed to determine its effectiveness in increasing seed set in young seed orchards, SMP was beneficial in a year of poor orchard pollen production, but ineffective in a year of good production (Bridgwater and Bramlett 1981). Problems encountered with SMP have included determining the appropriate amount of pollen to apply, and adapting equipment to forest tree seed orchard situations (Bridgwater and Trew 1981). Studies are currently underway to determine the

effectiveness of SMP in increasing the quantity of seed from specific crosses in mature loblolly pine seed orchards.

Another way to mass produce full sib families would be through vegetative propagation. Vegetative propagation methods receiving most attention are rooted cuttings and tissue culture. Ideally, vegetative propagules would be derived from mature, fully progeny tested genotypes, but success thus far with loblolly pine has been with juvenile material (van Buijtenen et al 1975; Mott et al 1977). Rejuvenation techniques such as those used by the AFOCEL group in France may hold promise for allowing rooting of mature genotypes (Franclet 1979). Work is underway to propagate mature loblolly pine trees with tissue culture (Mott 1981). If exisiting propagation methods for juvenile material could be made cost effective, it would be possible to mass produce full siblings by rooted cuttings or tissue culture. Results are not yet available from well-designed long-term studies comparing the performance of vegetative propagules and seedlings for loblolly pine, but the several now underway should give good answers. This information is needed before large scale regeneration programs with vegetatively propagated material begin.

Super-Intensive Roguing of First Generation Orchards

In the N.C. State Cooperative, seed orchards are rogued several times during their development. They are usually rogued to a final composition of 12-15 clones, and final density is on the order of 15-20 trees per acre. A constraint has always been to rogue lightly enough to maintain full seed production, but as excess quantities of seed become available, this is no longer a requirement. Additional genetic gain could be obtained if orchards were rogued to only the few best clones, at the expense of reducing seed yields.

While super-intensive orchard roguings appear favorable from a genetic gain standpoint, there are potential difficulties which may influence optimal clonal compositon in mature orchards. One obvious concern is the possible reduction in genetic variation through roguing to only a few clones. This has been a topic of much debate among forest geneticists for many years and the debate will likely continue for many more (Libby 1981; Zobel 1981). Electrophoresis studies with loblolly pine have shown that much allelic variation exists in seed orchards for loci that can be studied using this technique (Hunter 1977; Adams and Joly 1980). While the relationship of variation patterns at these loci and those for loci which influence adaptability traits are unknown, we do have studies underway to determine what might be the reduction in genetic variation at these loci from super-intensive roguing.

Another concern involves phenology. Lack of synchronization in flowering in orchards that have few clones could reduce potential gains through selfing and outside pollen contamination, and could further reduce genetic variability. Even with synchronization, pollen supply in the orchard could be reduced to a level where outside pollen contamination becomes a much bigger problem than in a fully stocked orchard.

Orchard roguings of this intensity are experimental at this time. One slash pine orchard with which we work has recently been rogued operationally to eight clones. Experiments are underway in a loblolly pine orchard to compare the effects of roguing to final densities of four, eight and twelve of the best clones.

## SUMMARY

Significant gains in growth rate, wood density, stem quality, and fusiform rust resistance have been made in one generation of genetic improvement of loblolly pine. The size of gains which will be realized at harvest depend upon rotation age, stand management, and type of product.

Challenges and opportunities in first generation improvement programs do not end as complete progeny test information becomes available, and seed orchards reach full production. Aggressive, ongoing programs will have shifted much of their developmental efforts toward the next generation but additional short-term gains in first generation programs may be possible. For organizations with large regeneration programs, small increments of gain can mean a large difference in profitability.

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# STRATEGIES FOR ADVANCED GENERATION ORCHARDS

J.P. van Buijtenen

*Principal Geneticist, Texas Forest Service*

*and Professor, Texas Agricultural Experiment Station*

*Texas A & M University, Forest Genetics Laboratory*

*College Station, Texas U.S.A.*

## ABSTRACT

The overall purpose of advanced generation breeding is to maximize the amount of genetic gain per year. To achieve this gain, one has to optimize the mating design, develop a good strategy to manage inbreeding, and shorten the breeding cycle by the use of flower induction and early selection procedures. The design of advanced generation seed orchards is, in principle, very little different from that of first generation orchards, but will require extra care to minimize crosses among related individuals.

## RÉSUMÉ

Le but principal de la reproduction précoce est de porter à son maximum le gain génétique annuel. Pour atteindre cet objectif, il faut optimiser le schéma d'hybridation, prendre les bons moyens pour éviter la consanguinité et comprimer le cycle de reproduction à l'aide de l'induction florale et de la sélection précoce. Le concept des vergers à génération précoce est peu différent de celui des vergers de première génération, mais il faut prendre plus de précautions afin de réduire au minimum les croisements entre individus apparentés.

## INTRODUCTION

Advanced generation orchards are considerably more complex than first-generation orchards and present a number of new problems and requirements. An advanced generation breeding system needs to be a stable system that can be recycled from generation to generation using the same procedure. In doing so, the genetic base will be narrowed and we are faced with the problem of managing inbreeding. There are several ways of doing this, which will be discussed in detail in the paper. Because of the inbreeding problem there is also a need for compatibility between the breeding procedures and the seed orchard layout, since the physical arrangements of the selections on the ground affects the degree of inbreeding of the resulting wind-pollinated seed. Finally there is a need for a means of adding new material into the system even after several generations of gentic improvement.

In the following paper, I am not proposing a specific system

that will solve all problems, but instead I shall explore some approaches to solving these problems. There are many possible solutions and the preferred solution will differ by species and region.

## BREEDING STRATEGIES FOR ADVANCED GENERATION ORCHARDS

### Goals

The overall goal for breeding for advanced generation orchards is to obtain the maximum amount of genetic improvement per unit of time.

This goal is to be achieved by appropriate mating designs, progeny test procedures and accelerated breeding procedures.

### Mating Designs

Several objectives may be pursued when developing advanced generation mating designs. The most important ones are to develop families from which 1) the GCA can be determined for specific parents; 2) the SCA can be determined for specific pairs of parents; and 3) the breeding population for the next generation can be selected.

A summary of mating designs is given in Table 1 together with some of the advantages and disadvantages. A theoretical review of the merits of the different mating designs (Namkoong and Roberds 1974; van Buijtenen 1976) is beyond the scope of this paper, but there are some practical considerations that are worth pointing out. To effectively determine GCA, it is important that each parent is involved in several crosses. It is usually best if the design can be arranged in small sets of crosses. A small set of crosses can be completed in a relatively short period of time and such a group can be kept together in the field. In looking at the designs, it is obvious that some designs such as disconnected factorials, disconnected diallels, and partial diallels can do a fair job of satisfying the principal objectives. Other designs such as the polycross or the circular mating designs each satisfies merely one objective. One has the alternative of settling on one design that will satisfy all the objectives or following a proposal made by the French several years ago to utilize a number of complementary mating designs each of which is quite simple and does the best job of satisfying a single objective.

### Progeny Test Designs

Progeny tests may have any number of goals such as early evaluation, ranking of families at the sampling stage, ranking of families at rotation age, evaluating specific traits such as disease, drought, and cold resistance, or evaluating actual growth and yield under operational conditions.

A summary of progeny test designs is given in Table 2. The physical layout of single tree plots and non-contiguous plots in the field is very similar. The main difference is that in non-contiguous

plots several trees, even though they are not adjacent to each other, are considered as one plot.

Table 1. Mating designs and Their Usefullness

| Mating Design | Cost | Objectives Served Well[1] | Efficiency |
|---|---|---|---|
| Nested | Low | sca | Low |
| Factorial (e.g. 4 tester scheme) | Moderate | gca, sca | Moderate |
| Completed diallel | High | gca, sca, sel | Low |
| Disconnected diallel | Moderate | gca, sca, sel | High |
| Disconnected factorial | Moderate | gca, sca, sel | High |
| Incomplete diallels | Moderate | gca, sca, sel | High |
| Circular matings | Low | sel | High |
| Single pair matings | Low | sel | High |
| Polycross | Low | gca | High |

[1] gca = determination of general combining ability.
sca = determination of specific combining ability.
sel = provide population in which to make advanced generation selections once gca is known.

Single tree plots, non-contiguous plots, and row plots are rather good at evaluating seedlings at an early age, about to the sapling stage, but once competition sets in, rankings may be different from rankings obtained in block plots where trees are competing with their siblings. For that reason, there is some question about their ability to evaluate families well at rotation age. Block plots can be used well for all purposes. However, their statistical efficiency is low, since very large tests are required and usually a great deal of site variation is encountered.

In order to obtain growth and yield data under operational conditions, it is necessary to put sample plots in operational plantings. As far as I know, no data of this sort are available yet and not much is known about the statistical precision of such a procedure. One can expect it to be rather low because of the amount of site variation encountered and the uncontrolled nature of operational plantings.

A problem that we have run into repeatedly in summarizing progeny test data is the difficulty of summarizing data across tests when each test contains a partial set of crosses with varying degrees of overlap among tests. It can be done but the statistical precision of the results is somewhat less than desirable. For that reason it would be advantageous to match the progeny test design and the mating design in such a way that entire sets of crosses can be field planted at the same time.

Management of Inbreeding

In a recurrent selection and breeding system, inbreeding eventually becomes unavoidable. It is therefore necessary to develop a strategy for the management of inbreeding. It is important to distinguish between the various populations involved in a breeding program. These populations are theoretically distinct, although in practice some of them are often combined. For this purpose, it suffices to consider the breeding population, the progeny test population, and the production population.

Table 2. Progeny Test Designs and Their Usefulness

| Progeny Test Design | Complexity | Cost | Well Served[1] Objectives | Efficiency |
|---|---|---|---|---|
| Single Tree Plots | High | Low | esp, sap | High |
| Non-contiguous Plots | High | Low | esp, sap | High |
| Row Plots | Low | Moderate | esp, sap | Moderate |
| Block Plots | Low | High | esp, sap, rot | Low |
| Sample Plots in Operational Plantings | Low | High | yield | Low |

[1] Abbreviations used:
esp = early selection procedures
sap = evaluation at sampling stage
rot = evaluation at rotation age
yield = growth and yield data.

The breeding population is composed of the trees and the progeny that are used to produce the selections for the next generation. The progeny test population is composed of the trees that are used to evaluate the parents from which they are derived. They may or may not be used to generate new selections. The production population consists of the seed and seedlings that are derived from the operational seed orchard.

In the seed orchard seed, it is desirable to minimize or completely eliminate all inbreeding since inbreeding results in a loss of vigor. However, in the breeding population it is possible to tolerate a certain degree of inbreeding, and under certain circumstances it might even be desirable. In the progeny test plantations, inbreeding needs to be managed very carefully since it tends to be confounded with general combining ability. If all progenies in the test are equally inbred there is no particular problem. As a matter of fact, it might make it easier to distinguish the desirable progenies. However, if some are inbred more than others they might be unfairly penalized.

Maintaining a large genetic base is one means of slowing down the rate of inbreeding. This conflicts, however, with the overall goal of maximizing the gain per unit of time, which requires the maximum selection intensity possible and would result in narrowing the genetic base and increased inbreeding. This is a situation that is in principle unresolvable. One needs to arrive at a compromise solution, balancing the need for immediate gain against the need to minimize inbreeding and retain the maximum number of genes in the population to insure long-term gentic gains. It is also important to preserve genes that may be needed in the future to meet unexpected requirements such as changing market demands or resistance to new diseases.

Effect of Mating Designs

Cockerham (1970) did some work several years ago on this and found that mating designs that avoid inbreeding as long as possible will begin to show rapid inbreeding once inbreeding starts. Other designs which allow some inbreeding right from the beginning will accumulate less inbreeding eventually. A circular mating design is one of those designs which falls in the second category.

Use of Co-Ancestry Matrix

A co-ancestry matrix (Falconer 1960) is a table which shows the degree of inbreeding to be expected when crosses are made among the parents included in the table. It is somewhat difficult to visualize the relationships since one has to look back two generations, a situation somewhat analogous to looking two moves ahead in a chess game. The method lends itself well to computer analysis, however, and can be a great help in planning crosses and determining the degree of inbreeding expected in progenies. The use of such a matrix enables one to carefully control the degree of inbreeding within the feasible limits.

Use of Breeding Groups

By subdividing the population into independent lines, limiting all crosses for breeding purposes to within group crosses, it is possible to have an inbred breeding population, but assure that the production population referred to earlier is entirely outcrossed. This seems to be a very nice way to have one's cake and eat it too (van Buijtenen and Lowe 1979).

## Accelerated Breeding

Another major consideration in advanced generation breeding and one aimed specifically at increasing the gain per unit of time is the development of accelerated breeding procedures. There are two aspects to this, the breeding cycle can be reduced both by inducing earlier flowering and by reducing the length of time needed to evaluate the progenies.

## Flower Induction

In several species such as Cryptomeria japonica, Douglas-fir, and loblolly pine, it has been possible to induce early flowering by a variety of techniques. Some of the main techniques in use currently are a) application of gibberellins, particularly in combination with water stress (Pharis 1975; Greenwood 1977); b) heavy fertilization; c) out of phase dormancy (Greenwood 1980); d) branch girdling, particularly to induce male flowering (Greenwood 1977); and e) the use of specially selected understock (Holmes 1981; Wright 1981). All of these methods have worked under certain circumstances and in combination can serve to reduce the flowering age by several years.

## Early Testing

Less progress has been made on early evaluation of families. In general, correlations between early height and diameter measurements and subsequent growth have been rather weak. Some recent experiments (Cannell et al 1978; Wexler 1980), however, show promise that some traits such as shoot-root ratio may be of value in selecting families at an early age for growth rate. Other traits such as rust resistance and drought resistance can easily be evaluated at an early age.

## How to Blend in Accelerated Breeding with Conventional Testing

Little thought has been given to this problem so far. It is obvious that it will not be possible to replace seed orchards at very short intervals every time a generation has been completed. It seems reasonable to assume that if accelerated breeding becomes a reality, one may go through several cycles in quick succession before incorporating the selected material into the main line program. A possibility for integrating the various methods might lie in a stepwise screening procedure. One might, for instance, begin by screening a large number of trees with early testing methods, then screening the most promising families with conventional progeny tests for a duration of about half the rotation age, and finally screen a very small number either as orchard mix or open-pollinated families to full rotation age in operational plantings. To my knowledge, no one has ever thoroughly evaluated such a procedure, but this may be the general direction in which we are moving.

# DESIGN STRATEGIES FOR ADVANCED GENERATION ORCHARDS

In a first-generation orchard one only needs to be concerned

with maximizing the crossing among clones and trying to minimize the pollination that may occur between ramets of the same clone. In advanced generation orchards one also has to be concerned about the relatedness among different clones in the orchards and the need to minimize or avoid mating between related clones. Similar designs can be used in advanced generation orchards and in first-generation orchards. They fall into two major categories: systematic designs and random designs.

Systematic Designs

In Figure 1, a design is shown that is used extensively within the Western Gulf Forest Tree Improvement Program. It is very convenient for first-generation orchards and also works well with advanced generation orchards. In this case, each of the ten positions in the design indicated by the numbers 1 to 10 is identified with a breeding group rather than with an individual clone. In such a case not only can members of the same breeding group be included in the same orchard, but it is also rather easy to include members of different generations in the same orchard. It is, for instance, not uncommon to mix some of the very best first-generation selections in the same orchard with some untested but promising second-generation selections. The main disadvantage of the systematic design is that, if two or three trees are rogued from the orchard in adjacent positions, rather large holes will occur throughout an entire orchard block.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 |
| 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 |
| 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 |

Fig. 1. Systematic seed orchard design used by Western Gulf Forest Tree Improvement Program.

Random Designs With Use of Breeding Groups

One can randomize the breeding group numbers and assign trees from breeding groups to the appropriate positions. Again it is possible to mix the generations. Experience shows, however, that even in randomly designed orchards very large holes can occur during roguing because of chance occurrences of trees that need to be removed from the orchard.

Random Designs Without Breeding Groups

These are a nightmare to work with. It is almost impossible to design such an orchard by hand without making several mistakes. One needs a computer program to assign the positions and analyze the relatedness of the trees to be included in the orchard. One does need a rather large number of unrelated parents to complete such an orchard and the problem will become more severe in further generations.

## SUMMARY AND CONCLUSIONS

In the following few paragraphs I would like to summarize the preceding, really giving in to my personal biases.

a) One of the promising approaches to the development of mating designs is the use of complementary mating designs using very simple mating schemes each of which serves a single objective very well.

b) The most promising approach to managing inbreeding seems to be the use of breeding groups, allowing one to get inbreeding within the breeding population without getting inbreeding in the production orchard. If co-ancestry matrixes are used while planning crosses within a breeding group, it is possible to very closely control the amount of inbreeding in the breeding groups.

c) It may be possible to blend in accelerated breeding methods with conventional ones, by the use of a stepwise screening procedure. This should result in considerable savings in the cost of progeny testing.

d) Either systematic or random seed orchard designs can be used for advanced generation seed orchards. If they are used in combination with breeding groups, neither one is particularly difficult. If used without breeding groups, it is virtually a necessity to develop a computer program to assign the trees to their positions.

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# FIELD EXCURSION

SAANICH PENINSULA SEED ORCHARDS

ILLUSTRATING:

Capital Development Phase
Mount Newton Seed Orchard

Establishment Phase
Lost Lake Seed Orchard

Production Phase
Saanichton Seed Orchards

# MOUNT NEWTON SEED ORCHARD

S.W. Lorimer *Crown Zellerbach Canada Ltd.*, and D.E. McMullan *British Columbia Forest Products Ltd.*

## INTRODUCTION

The site is being managed as a joint venture between British Columbia Forest Products Limited and Crown Zellerbach Canada Ltd. The 40 hectare property was purchased in 1979 with BCFP owning an undesignated 60% (24 hectares) and Crown Zellerbach 40% (16 hectares). The majority of the site is being managed as part of the Coastal Tree Improvement Council cooperative B.C. Forest Service-Industry tree improvement program. BCFP is responsible for the management of orchards 29 (Abies amabilis) and 20 (western hemlock), while Crown Zellerbach looks after orchards 34 (Douglas-fir), 38 (yellow cedar) and 40 (western red cedar). A small orchard supplying Douglas-fir seed for the private lands of both companies will also be established over the next few years on a portion of the site.

## MANAGEMENT

Direct supervision of the orchard is the responsibility of the Seed Orchard Supervisor, Brian Stretch, who reports directly to a Management Committee which is composed of the chief forester, silviculturist and an accountant from each company. Back-up supervision and assistance in site development is provided by a salaried employee. Annual and monthly operating financial statements are prepared by the accountant at the Crofton Logging office of BCFP.

Advice concerning orchard management and layout design problems is being provided to both companies by Don Lester, Ph.D., consulting geneticist, employed by Crown Zellerbach Corporation of Oregon. Other specialist advice is being sought as projects develop.

## CAPITAL DEVELOPMENT PROGRAM

Since purchase of the site in 1979, general site improvements have included installation along the total perimeter of a chain-link fence, perimeter and some internal drainage, construction of access roads, upgrading and expansion of the small house to provide a residence for the orchard supervisor, structural repairs and re-roofing of the barn, rough construction of the holding site and service area, replacement of the power line along the access road, construction of an office and meeting room complex within the barn, and construction of a 43 million litre reservoir and lower sump as the first phase of the irrigation system. The majority of the required capital development projects are to be completed by mid-1981.

## ORCHARD DEVELOPMENT

The sites for the orchards are located as indicated on the attached map and were assigned on the basis of species/site suitability.

Outplanting of the various orchards is scheduled to start in 1982 and be completed by the end of 1985. Planting spot preparation will be undertaken prior to field establishment. Selections of the parents is being undertaken through the cooperative selection program of the CTIC with propagation being undertaken at the Mesachie Lake Propagation Centre of the B.C.F.S. Cultural practices for the first few years will concentrate on vegetative growth in order to ensure successful orchard establishment.

## GENETIC IMPROVEMENT

Breeders employed by the B.C.F.S. are working towards developing information which would permit eventual roguing of the fir and hemlock orchards. No breeders have yet been assigned to the balsam, cedar and cypress programs. Parental selections for all orchards is based largely on parent tree quality and the need for obtaining a good geographic distribution.

## ORCHARD SUMMARY

| Orchard No.[1] | Species | Area Under Orchard | Establishment Goal | No. of Parents | Estiamted Annual Seed Yields |
|---|---|---|---|---|---|
| 29 | Balsam (A. amabilis) | 7.7 ha | 1984 | 100 | 1,380,000 by 1994 |
| 30 | Western Hemlock | 8.2 | 1984 | 100 | 2,350,000 by 1991 |
| 34 | Douglas-fir | 5.2 | 1983 | 80 | 2,340,000 by 1994 |
| 38 | Yellow cedar | 1.2 | 1985 | 120 | 670,000 by 1991 |
| 40 | Western red cedar | 0.6 | 1984 | 100 | 420,000 by 1988 |
| | | 22.9 ha | | | |

The orchard size, numbers of parents, seed needs and estimated yields through time were determined by members of the Technical Planning Committee of the Coastal Tree Improvement Council

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[1] Orchard planting zones

| Orchard No. | Planting zone |
|---|---|
| 29 | Johnstone Strait, Western Vancouver Island |
| 30 | Western Vancouver Island |
| 34 | Johnstone Strait |
| 38 | Johnstone Strait, Northern Vancouver Island Western Vancouver Island, Eastern Vancouver Island |
| 40 | Johnstone Strait, Eastern Vancouver Island, South Coast Mainland |

## MOUNT NEWTON SEED ORCHARDS

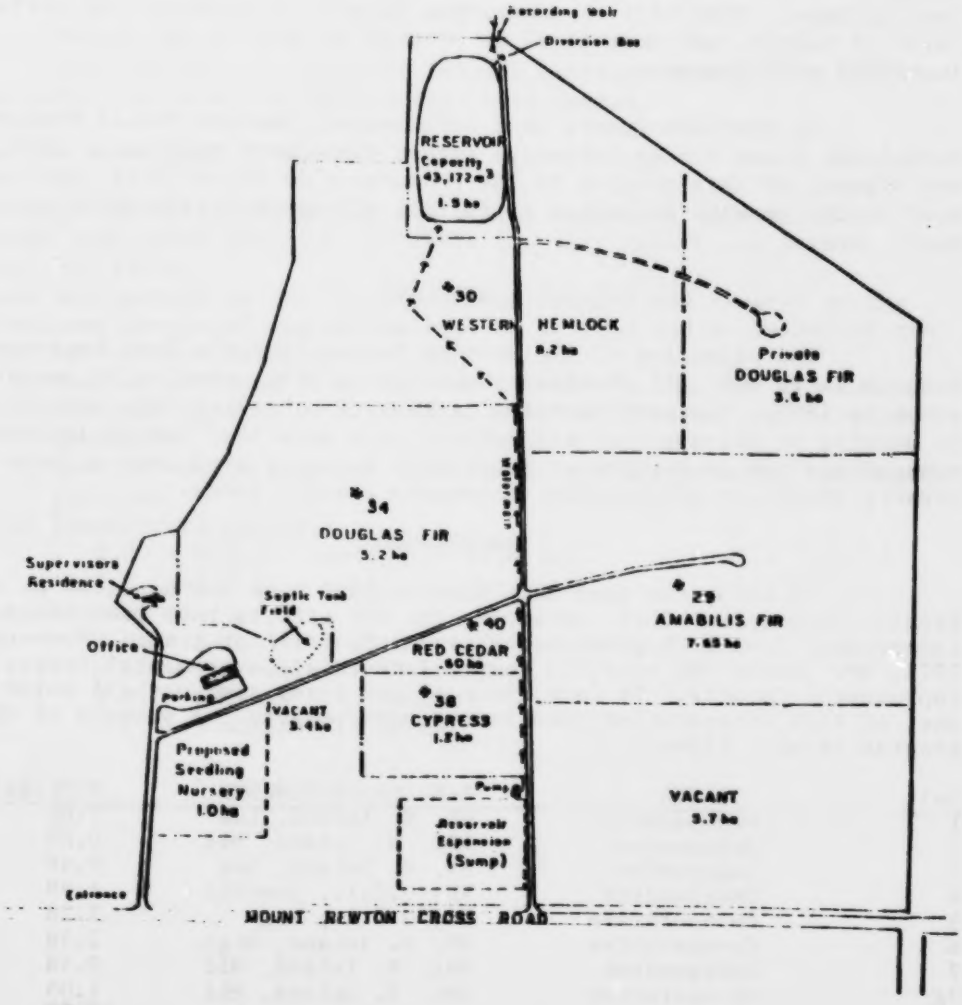
### Site Organization Showing Orchard Locations

Existing Roads _____

Proposed Roads ====

Orchard Boundaries __··__··__

Scale 1 cm = 50 m



# LOST LAKE SEED ORCHARD

W.L. McMullan

*Western Forest Products Limited*

## INTRODUCTION

Western Forest Products is a large forest industrial company whose basic forest management policy is to maximize the quality and quantity of the annual allowable cut. However, the acreage base that is so essential for growing the forest crop has been slowly diminishing through losses to highways, gravel pits, parks, hydro lines, and environmental constraints. To provide for the future wood requirements of our manufacturing plants it will be necessary to produce more wood on less acreage. This will be imperative if only to maintain our current level of supply, but more so if we propose to provide our future increased wood demands.

To overcome future wood deficiences, Western Forest Products formulated plans for an Intensive Forest Management Program in 1971. The key element of this program is the production of genetically improved seed in the amounts necessary to fulfill all company reforestation requirements.

## OBJECTIVE

The objective of the Western Forest Products Tree Improvement Program is to meet all planting requirements with genetically improved stock by 1985. The only practical method of achieving this objective is to develop an all-species seed orchard on a site that can be intensively managed for the production of gentically improved seed used to grow nursery stock for outplanting on company managed lands.

## BACKGROUND

In 1973, the Lost Lake Seed Orchard site was acquired on the Saanich Peninsula. Until recently, the WFP efforts have been completely independent from both governmental and industrial programs. However, in 1979, WFP joined the recently formed Industrial/Governmental Coastal Tree Improvement Council. To date, four of our seven seed orchard units are part of this co-operative tree improvement program. A summary of the WFP program is as follows:

| Unit | STATUS | SPECIES/PROVENANCE | SIZE(Ha) |
|---|---|---|---|
| 1 | Co-operative | WH, N. Island. Low | 3.66 |
| 2 | Independent | WRC, N. Island, Mid | 0.85 |
| 3 | Independent | SS, N. Island, Low | 0.48 |
| 4 | Independent | WH, Q.C.I., Low/Mid | 1.09 |
| 5 | Co-operative | SS, Q.C.I., Low | 2.28 |
| 6 | Co-operative | WH, N. Island, High | 2.38 |
| 7 | Independent | WRC, N. Island, Mid | 0.58 |
| 7A | Co-operative | WRC, N. Island, Mid | 1.05 |
| | | Total: | 12.37 |

## PROGRESS TO DATE

1973 - 27.44 hectare seed orchard site purchased on the Saanich Peninsula.
1974 - 8,300 meters of drain tile installed.
- propagation facilities constructed.
1975 - conversion of old farm structures into workshop, storage areas, office and staff quarters.
- landscaping, upgrading power supply and water lines.
1976 - paving entrance road and parking lot.
- construction of additional propagation facilities.
1977 - installation of irrigation system initiated
1978 - installation of 2,000 meter chain link fencing initiated.
- farm tractor and accessories purchased.
1973 - 1980 - over 700 plus/parent trees selected, cuttings collected and propagated by rooting.

## PROPAGATION

Over the yars, a total of 182,756 cuttings were set in the rooting beds. To date, 19,229 cuttings have rooted.

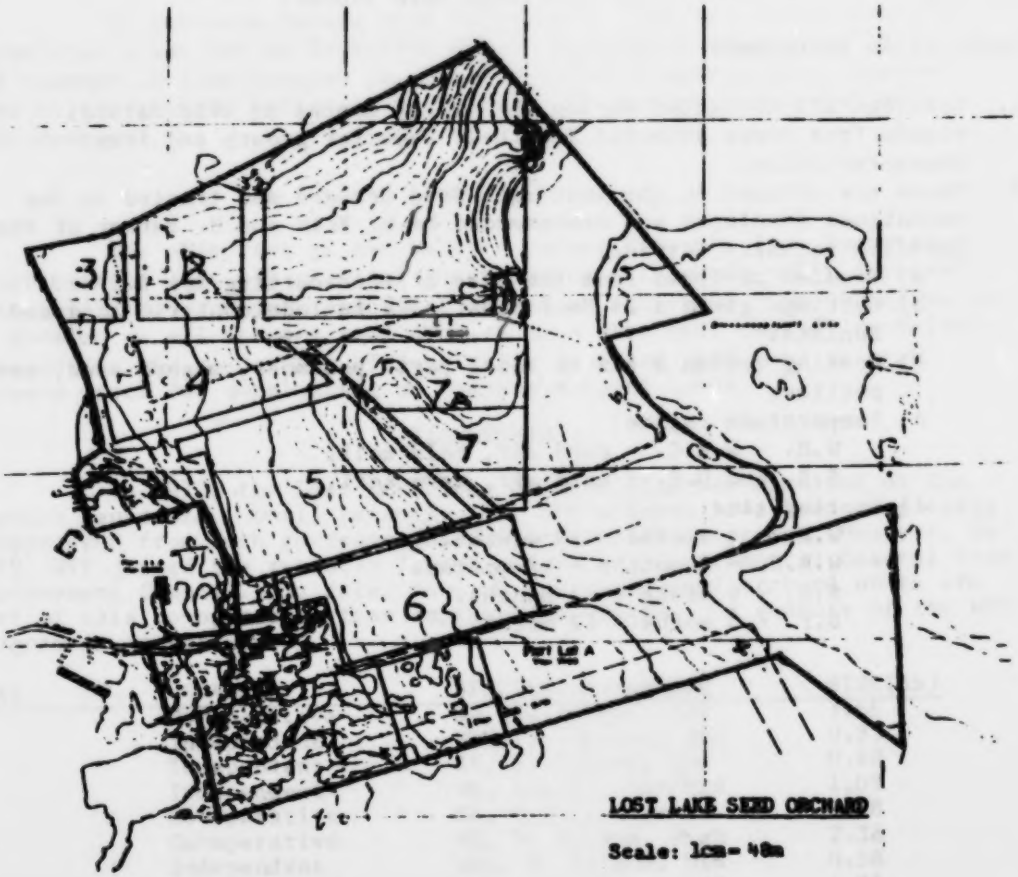
Propagation Techniques

1. Cuttings are collected during the winter months in wild natural stands from trees selected for their superior growth and form characteristics.
2. These are shipped to the Lost Lake Seed Orchard and treated by the techniques developed and recommended by H. Brix and H. Barker of the Canadian Forestry Service:
   a) Needles stripped from the base of each cutting for 2.5 cm.
   b) Cuttings given a 24 hour basal soak in Indolebutyric acid and Benlate.
   c) Rooting medium a mix of equal parts peatmoss, washed sand, and perlite.
   d) Temperature regime:
      W.H. - W.R.C. - cold air, cold soil.
      S.S. and D.F. - cold air, warm soil.
   e) Rooting time:
      W.H. - 6 months - 24 months.
      W.R.C. - 3 months - 18 months.
      S.S. - 6 weeks - 12 months.
      D.F. - 3 moths - 12 moths.

## LOST LAKE SEED ORCHARD

### Site Organization Showing Orchard Locations

| UNIT | ORCHARD REG. NO. | SPECIES | PROVENANCE |
|---|---|---|---|
| 1 | 26 | W.H. | N. Island, low |
| 2 | | W.R.C. | Q.C.I., mid |
| 3 | | S.S. | N. Island, low |
| 4 | | W.H. | Q.C.I., mid |
| 5 | 42 | S.S. | Q.C.I., low |
| 6 | 27 | W.H. | N. Island, high |
| 7 | | W.R.C. | N, Island, mid |
| 7A | 28 | W.R.C. | N, Island, mid |



# SAANICHTON SEED ORCHARDS

**Anita Pashler**

*Pacific Forest Products Limited*

## INTRODUCTION

At Pacific Forest Products we tend and harvest trees on self-regulated crown granted lands. These lands were purchased from the Esquimalt and Nanaimo Railway Co. and others starting in 1962. Our objective in conducting our forestry business is to manage our private forest land base to yield the highest possible return on our investment consistent with a continuous supply of wood.

The company manages 127,500 ha of privately owned forest (0.24 of British Columbia's forested area), most of which is located on the south east side of Vancouver Island, with additional supplies of crown lands on the west side of Vancouver Island as well as on the mid coastal Mainland.

The forest management policy of P.F.P. involves an intensive forest management program based on forest site classification. Forestry activities include prompt reforestation, spacing, fertilization, commerical thinning, protection and tree improvement. The Saanichton Douglas-fir seed orchards illustrate the company's commitment to intensively manage our private forest lands.

## OBJECTIVE

The objectives of the seed orchard are: a) to produce improved seed for reforestation, and b) to generate advance generation populations through control crossing. The HE and LE orchards are designed to provide 25 kg of seed per annum at age 15 years. Similar productivity is expected from the FS seed orchard.

## BACKGROUND

The 26 ha property was purchased in 1965. The site characteristics of summer drought and 2000 plus hours of annual sunshine appear to be responsible for frequent heavy cone crops in the area.

At this time, 11 of the 26 ha are developed in Douglas-fir. All orchards are privately owned and are designed to provide improved seedlings for reforestation on company lands. Some statistics on current seed orchard status are given below:

Current Seed Orchard Status

| Orchard | Type | Status | Species/Provenance | No. Clones or Crosses | Acre (ha) |
|---|---|---|---|---|---|
| HE | o.p seedling/clonal[1] | private | F/high elev.[2] | 63 | 3.4 |
| LE | o.p seedling/clonal | private | F/Low elev. | 72 | 1.3 |
| FS | c/c/ seedling[3] | private | F/low to mid | 145 | 6.0 |

[1] o.p. - open pollinated
[2] F - Douglas-fir
[3] dc.c. - control cross

The high elevation and low elevation seed orchards were grafted between 1966 and 1968; the open pollinated seedlings were 2 + 0 plugs planted in 1971. The full-sib seedlings were planted in 1975 as 1 + 1 transplants. Just over 100 crosses are represented in the FS orchard to date.

## PRODUCTION INFORMATION

Cone and seed production at the Saanichton Douglas-fir seed orchards from 1976 to 1980 is given in Table 1. The 1980 seed crop of 26.55 kg has a projected seedling production of approximately 2.0 million. Cone crop estimates for 1981 predict a lower yield. This is consistent with the pattern of cone production established in the Saanich Peninsula seed orchards, namely a good crop about every 2 years.

Table 1. Douglas-fir Seed Orchard Cone and Seed Production

| Year | Seed Orchard | Cone Production in HL | Seed Production in Kg | Seed Yield in Kg/hL |
|---|---|---|---|---|
| 1976 | high elevation | 29.77 | 15.85 | 0.40 |
| 1977 | high elevation | | 2.12 | |
| 1978 | high elevation | 57.9 | 22.37 | 0.39 |
| | low elevation | 3.6 | 0.96 | 0.27 |
| 1979 | high elevation | 45.0 | 11.6 | 0.26 |
| 1980 | high elevation | 49.14 | 25.0 | 0.50 |
| | low elevation | 1.8 | 0.6 | 0.33 |
| | full-sib | 2.16 | 0.95 | 0.44 |

## MANAGEMENT INFORMATION

A special feature at the orchard is the solid set irrigation system used to delay flower bud opening past the local flowering period so that contamination from local pollen will be minimal. The system was applied to the 1976 and 1978 seed orchard cone crops. In both years phenological and pollen flight data showed that the cooling treatment kept the female reproductive buds unopened through the major portion of the local pollen flight period in approximately 76% of the Douglas-fir clones in the orchard. Cooling followed by bulk pollination is estimated to give 85-90% control over contamination.

Results of the seed and cone insect control study (Heath, 1980 Pacific Forest Products Internal Report) carried on at the seed orchard in 1980 are presented in Table 2. The objective was to assess the efficacy of an insecticide spray in comparison to and in conjunction with the irriagation cooling system to reduce seed losses due to insect damage. It was estimated that the application of an integrated pest/irrigation cooling system control program would protect over 1 million seeds annually in periods of heavy infestation.

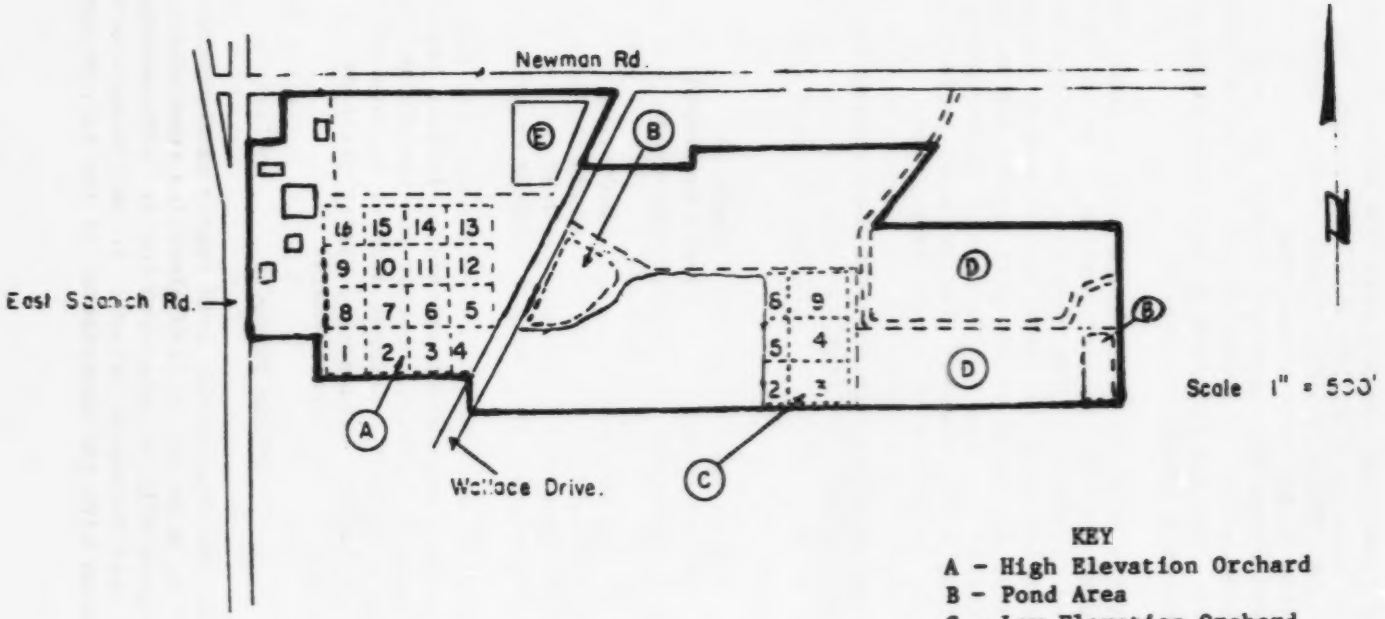
Table 2. Impact of Contarinia oregonensis on Seed Production at the Pacific Logging Seed Orchards

| Treatment | Mean No. Filled Seeds per cone | Mean No. Seeds Destroyed per cone | % Seed Destroyed |
|---|---|---|---|
| Insectcide & Delay | 19.96 | 0.09 | 0.46 |
| Delay Alone | 19.13 | 1.24 | 6.40 |
| Insecticide Alone | 11.43 | 0.33 | 2.80 |
| Control | 15.84 | 1.88 | 11.90 |

Standard orchard management procedures include reproductive bud delay, frost protection, irrigation, booster and control pollination, weed control and insect control. Several orchard surveys are undertaken throughout the year to improve management, assist planning and develop a data base for all clones in the seed orchard.

## FUTURE PROJECTS

Emphasis on the Douglas-fir tree improvement program will be continued with specific interest in high elevation seed production. A tree improvement program will be developed for dry site western hemlock on company lands on east Vancouver Island. In addition, a Sitka spruce seed orchard is planned with the cooperation of the B.C. Ministry of Forests.




KEY

A - High Elevation Orchard
B - Pond Area
C - Low Elevation Orchard
D - Full-sib Orchard
E - Container Nursery
1 ... 16 - Orchard Blocks

SAANICHTON SEED ORCHARDS

Site Organization Showing Orchard Location

# SEED TECHNOLOGY FOR SEED ORCHARDS

Chairman:

George Edwards
Canadian Forestry Service
Victoria, B.C.

# CONE COLLECTION AND HANDLING FOR SEED ORCHARDS

B.D. Haddon

*Petawawa National Forestry Institute*
*Canadian Forestry Service*
*Chalk River, Ontario*

## ABSTRACT

A wide variety of strategies and equipment is available for the collection of cones and seeds. Some are well suited to application in seed orchards while others do not meet the constraints inherent to seed orchards. The seed orchard manager can choose between manual and mechanical techniques and between harvesting before and after seed dispersal. Improved technology is not as important in cone handling as attention to logistics and administrative procedures.

## RÉSUMÉ

Il existe une grande variété de méthodes et d'équipement pour la récolte des cônes et des graines. Certains conviennent aux vergers à graines tandis que d'autres ne satisfont pas aux contraintes qu'on y trouve. Le directeur du verger a le choix entre des techniques manuelles et mécaniques et peut récolter soit avant, soit après la dispersion des graines. Pour la manutention des cônes, les nouvelles techniques ne sont pas aussi importantes que la logistique et les méthodes de gestion.

## INTRODUCTION

In a discussion of cone collection and handling for seed orchards, it seems logical to first consider the unique features and the constraints to seed orchard cone collection and handling. Among those features unique to seed orchards is the fact that the trees are extremely valuable as are the seeds to be collected from them. There are both clonal and seedling seed orchards, a fact which may affect cone collection and handling. It seems likely that accessibility to the trees will be greater in seed orchards than in natural stands.

A number of constraints, which are not necessarily unique to seed orchards, limit the options available for cone collection and handling for seed orchards. Damage to the trees cannot be tolerated because they are so valuable. Because the seeds are so valuable, no loss can be tolerated. Terrain can vary tremendously among Canadian seed

orchards. Seed dispersal dates vary among individual parent trees in an orchard. A potential limiting factor is the availability of labour during the cone collection period and one is always faced with the vagaries of weather during the collection period.

## CROP ASSESSMENT

Before committing resources to cone collection, and hence every phase of handling and seed processing subsequent to collection, the seed orchard manager must decide whether a cone crop warrants collection. He must take account of genetic considerations; was flower production adequate for an acceptable genetic mix in the resultant seeds? He must take account of insect damage; are there actually sufficient quantities of sound seeds in the cones to warrant the commitment of resources for collection from a particular orchard?

The determination of seed development and the probable time of seed maturation are part of crop assessment. Only when all the biological factors are accounted for and a collection strategy worked out that takes into account such factors as availability of labour and equipment can the seed orchard manager determine the optimal scheduling of cone collections.

## COLLECTION

### Before seed dispersal

#### Manual cone collection

Any method of cone collection prior to seed dispersal offers the possibility of maintaining seedlot identity with respect to mother trees.

Many foresters will attest to the value of tree-climbing for cone collections (Yeatman and Nieman 1978, 1979). Topography presents no problem to this technique. However, it is unlikely that damage to trees can be kept to acceptable levels when they are climbed every year. A high level of training and skill is necessary for tree-climbing to be a safe and efficient technique.

Ladders, particularly tripod ladders, are useful tools (Yeatman and Nieman ibid.). Terrain would have to be very rough to restrict their use and trees are not subject to damage. However, ladders are restricted in height and are rather cumbersome. They must be moved around each tree to yield access to the entire cone-bearing crown.

"Cherry-pickers" or bucket booms can be mounted on a variety of vehicles. They offer greater maneuverability around tree crowns than ladders, but their use is restricted by terrain and the spacing between trees. They could damage trees through abrasion and soil compaction, especially as the larger the boom, the larger the vehicle required on which to mount it. A number of self-propelled aerial lift platforms are marketed for work in fruit orchards and light industrial settings, and

have been used to advantage in British Columbia seed orchards. Innovations and improvisations have included such things as mounting scaffolding on the back of a truck (D.A. Skeates, Ontario Ministry of Natural Reosurces 1981, pers. comm.). Dooley et al (1981) have reported on a study of man positioners applicable to the manual collection of cones and have recommended a complement of man-lift equipment.

Seal (1957) reported a technique which may have application with mature, large crowned trees. For work in species with small cones, such as Thuja and Tsuga, the collector makes use of a triangular "Tree Net", usually 36 feet (11 metres) across the base and 40 feet (12 metres) high, made of Italian hemp with a 12 inch (305 mm) by 12 inch mesh. The apex of the net is run up into the crown by a carriage block on a guy line and, by means of guys from the base of the net, it is spread so as to partly envelope the crown. The collector lies in the net and picks the small cones by hand, putting them in a shoulder bag.

Mechanical cone collection

A variety of machines have been developed for the separation of cones from slash, a feature which precludes their use in seed orchards, but at least one company has developed equipment for the collection of cones from standing trees.

Fandrich Cone Harvesters (Dr. H. Fandrich, Fandrich Cone Harvesters Ltd., Clearbrook, B.C. 1981, pers. comm.) are designed to collect seed bearing cones with the aid of a helicopter or crane. Generally, the harvester is lowered over the top 3-5 metres of the tree and then raised to collect the cones which fall into a bin surrounding the harvester head. When full, the bin is dumped at a central loading site. The Fandrich Balsam Rake was developed for cones larger than 40 mm in diameter, using specially designed fingers to strip cones from branches. The Fandrich Rotorake has rotating fingers that knock the cones from branches into a holding bin. The two rotating drums to which the flexible fingers are fastened are powered by a gas engine. The company claims that because damage to trees is minimal, Rotorakes can be used with a crane in seed orchards.

Other concepts

Top pruning or "topping" seems to be a controversial topic. It has been considered both as a general collection technique (Slayton 1969) and for crown management in seed orchards. Although biological constraints preclude its use for some species, such as Pinus, other species such as white spruce (Picea glauca (Moench) Voss), seem well suited to this treatment (Nienstaedt 1981). The objectives of the treatment when used for crown management are to keep crowns low for easy cone collection and to increase cone yield.

Artificial ripening has been successfully applied to a number of species (Winston and Haddon 1981) and could be applied to any cone collection technique (before seed dispersal). Artificial ripening can give the seed orchard manager a longer collection period, facilitating the deployment of labour and equipment and possibly reducing squirrel depredation. In some cases it serves to precondition seeds in that the

requirement for stratification is eliminated, even after regular seed storage (Haddon and Winston 1982).

After seed dispersal

Mechanical seed collection

Mechanical collection of seeds after dispersal reduces labour costs and eliminates extraction costs. The collector is assured of seed ripeness but cannot usually maintain seedlot identity.

Mechanical tree shakers, either self-propelled or mounted on a tractor or truck, have been developed and tested. Many consider this technique of cone removal unsatisfactory (Hallman and Casavan 1979), while others view it as practical (Moini and Miles 1981). Although tree shakers have usually been used for cone collection before seed dispersal, a variation has been reported in the USSR (Gukov 1973), wherein the trees are shaken by a hand-held modified power saw to hasten the dispersal of seed from open cones. The trees are shaken during periods of calm weather and the seed falls onto tarpaulins laid out on the ground.

The Georgia Forestry Commission has further mechanized this concept for application in loblolly pine (Pinus taeda L.) seed orchards (Wynens and Brooks 1979). Prior to cone opening, polypropylene netting is laid on the ground, using a tractor to pull the netting off large rolls. The netting is fixed to the ground and at the appropriate time a tree shaker is used to hasten seed dispersal from open cones. Fallen seeds and other debris which lands on the nets is windrowed and then mechanically collected. A modified peanut combine is used to separate the seeds from needles and other debris. Further refinements and mechanization of the system are under development, including an "Orchard Netting Machine" which gathers the netting and its collected material, at the same time separating the needles from the seeds (R.G. Hallman 1981, pers. comm.).

A variety of vacuum seed harvesters have been developed for the collection of fallen seeds without the aid of tarpaulins or netting. The advantages of the Bowie Vac-U-Seed Harvester, developed for use in the Southern Region of the U.S.A., have been enunciated by Hallman (1981) and could be extended to all forms of mechanical seed collection after dispersal:

"1. Extends the harvesting season from about 2 weeks to 2 months.

2. Eliminates the need for ladders and lift trucks, permitting orchard managers to let their trees grow taller because no climbing is involved, therefore extending the useful life of the trees.

3. Reduces collection costs compared to hand collection."

Calculations resulting in the last conclusion included costs of turf management necessary for the successful operation of the machine. The disadvantages of the harvester have also been enunciated:

"1. The orchard floor requires extensive preparation for the machine to operate well.

2. The harvester is noisy and produces large quantities of dust.

3. It does not operate well when the ground is wet.

4. The harvester has had a number of mechanical problems that have been largely corrected, but minor design changes still need to be made."

Two other considerations, which apply equally to the Orchard Netting Machine and other sophisticated machinery, are limitations imposed by terrain and portability from one seed orchard to another.

A report from France (Bastide and Gama 1980) describes two types of vacuum seed harvesters which are much smaller than the self-propelled Bowie Vac-U-Seed Harvester. The first, designed for beechnuts, weighs only 14 kg empty and can be carried on a man's back. The second, larger machine was designed for acorns and at present it is wheeled around on a small trailer. Again, the authors report that neither machine works well under wet conditions.

New concepts

Several years ago the idea occurred to me of enclosing trees in a mesh envelop but I dismissed it as impractical. Apparently the idea has occurred to others and it has been published in "An Analysis of Seed and Cone Collection" (Hallman and Casavan 1979). Seeds would be caught in the envelope as they are released, and a spout or trough at the bottom of the envelope would convey them to a container on or near the ground from which they could be collected. Seedlot identity could be maintained. Rodent and bird depredation would be eliminated if the mesh material was tough enough to resist chewing.

The technology of injecting trees is developing rapidly, and it may soon be possible to inject a compound which would promote the timely formation of abscission layers so that cones would fall out of the trees.

## HANDLING

Stein et al (1974) described handling and storage of cones to avoid losses and degradation of quality. Seed orchard material, in my view, need not be handled in any special way. Unfortunately, in many cases, cone handling is treated in a casual fashion. This is certainly not acceptable with seed orchard seeds. Improved technology is not as important in cone handling as is attention to logistics and administrative procedures. One must never forget the fact, as expressed by Wang and Fogal (1979), that "seeds reach their highest quality at physiological maturity, and they degenerate from then until planting, with the rate depending upon the degree of deviation from optimum conditions in the subsequent phases from harvesting to seeding".

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# SEED PROCESSING

Oscar Sziklai

*Faculty of Forestry*

*U.B.C., Vancouver, B.C.*

## ABSTRACT

Seed extraction is identified as a critical phase in providing seeds for artificial regeneration. All extraction methods are potentially harmful and only the most efficient, least damaging systems should be used for seed orchard seeds. Extraction without the use of artificial heat is recommended. Rotating Drum extractors should be used when artificial drying is required.

## RÉSUMÉ

On y établit que l'extraction des graines est une étape critique de la production de graines destinées à la régénération artificielle. Toutes les méthodes d'extraction sont potentiellement dommageables, et, dans le cas des semences de vergers à graines, on ne devrait employer que les plus efficaces et les moins dommageables. On recommande de ne pas utiliser de méthodes qui font appel à une source artificielle de chaleur, mais si c'est nécessaire, on devrait utiliser des extracteurs à tambour rotatif.

## INTRODUCTION

The increased demand for abundant and improved forest tree seeds brought into existance the seed orchard concept, which was first emphasized by Bursdorf (1787), and later Sylven (1918), Fabricius (1922), Oppermann (1923), Bates (1928) and Feilberg and Soegard (1975).

The first seed orchard was established in Scotland in 1931 with the intention to produce back-cross larch seeds. Presently approximately 20,000 ha of seed orchards have been established in the world. The largest total seed orchard area is reported from U.S.S.R. (10,670 ha), China (4,264 ha), U.S.A. (2,550 ha) and Japan (1,530 ha). On the Pacific Coast (Wheat and Bordelon 1980), Oregon had established by 1980, 359.2 ha, Washington 167.8 ha and B.C. 120.5 ha of seed orchards. Since many of the early orchards are already in the production phase, more and more emphasis is placed in obtaining:

a) high quality viable seeds through improved seed processing,

b) genetic parameters - ease of extraction, seed weight, germination energy, and germination capacity: to enhance roguing and increase gains in cone and seed yeilds from the

next generation orchards.

## SEED PROCESSING

Seed processing commences with collection, proceeds through the pre-curing followed by extraction, dewinging, cleaning, testing and then the seeds are placed in storage till sowing in the nursery (Fig. 1).

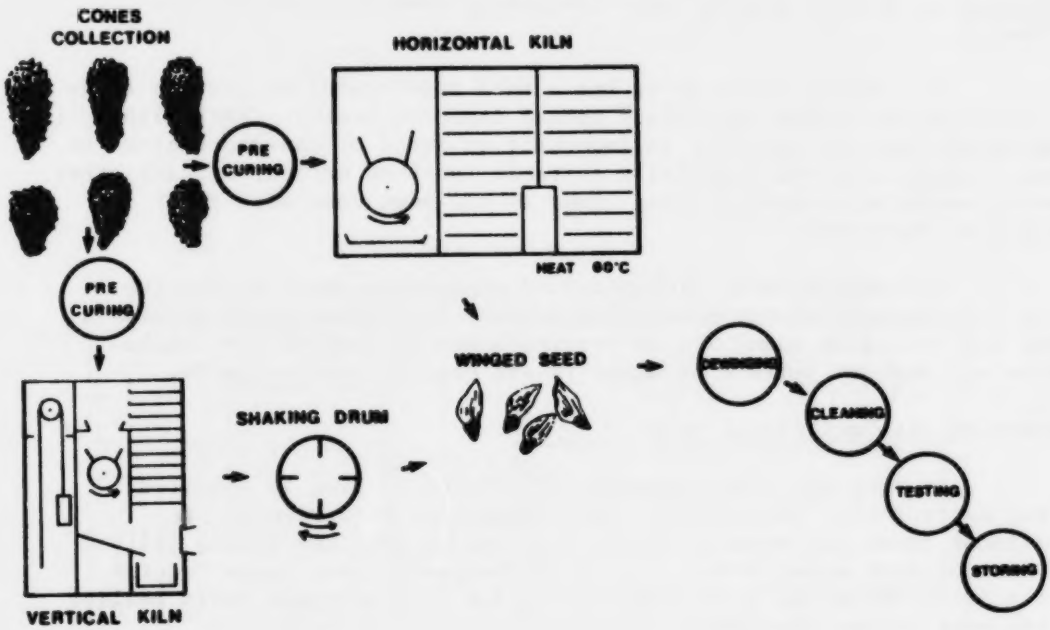



Fig. 1 Simplified scheme of seed processing

Among these steps - due to time constraints - the seed extraction phase will be discussed to suit the small lot size so important for the future success of the seed orchard.

Bulk, commercial or run-of-the-mill seed extraction is characterized by large quantities of cones, frequently over in 500 hl. Seed extractors were designed for these large quantities of cones, partially or fully fulfilling the three important requirements of seed extraction:

1. to provide optimum temperature
2. to remove moisture, and
3. to release seeds.

Extraction without artificial heat

According to Turnbull (1975), the extraction could be carried out without artificial heat, which is an important means of extracting seeds in the temperate, subtropical and tropical regions.

a) Drying in the open, when fruits are spaced on canvas, polyethylene sheets, fine meshed screens or sometimes on clean and level ground. Pinus ponderosa in Utah, Pinus kesiya in the Philippines, Pinus pinaster, and Pinus halepensis in Italy, Quercus petrea and Fagus sylvatica in Hungary are the most frequently used examples of this method.

b) Drying under cover has a main requirement to provide ample air circulation around the thinly spread layer of fruit. Controlling temperature and air humidity is important to avoid a "case-hardening" of cones. Abies spp. are especially suitable for this method, but any other species could be processed under cover as has been done with Pinus radiata in Australia.

The availability of controlled greenhouse space during the early fall in many of our developing nursery facilities could provide a cheap and efficient means for extracting seeds of Douglas-fir, Sitka spruce and western hemlock produced in our coastal seed orchards.

Extraction with artificial heat

In cool and humid regions, artificial heating is required during extraction. Furthermore, the temperature requirements of serotinous cones are usually higher than can be obtained during fall in the open or even under cover; e.g. fresh lodgepole pine cones require 52.5 $\pm$ 5.7°C while old cones need 54.6 $\pm$ 5.8°C to melt the resin sealing on the cone scales (MacCauley, 1975).

a) Stationary tray kilns are the simplest means of seed extraction (Fig. 2).

Cabinets with trays of drawers in stove-heated rooms with portable trays are the most frequently used models. Due to uneven heat distribution, extraction time is longer - 3-4 days - than in a fully controlled plant. Seed quality varies and depends on the individual operator.

b) Progressive kilns are characterized by controlled heated air flow, which increases in temperature - usually from 30°C to 60°C - and decreases in moisture content progressively during the drying period.

The two main types area:

1. Kapper - Gogolicin or vertical,

2. Pentz or horizontal flow kilns.

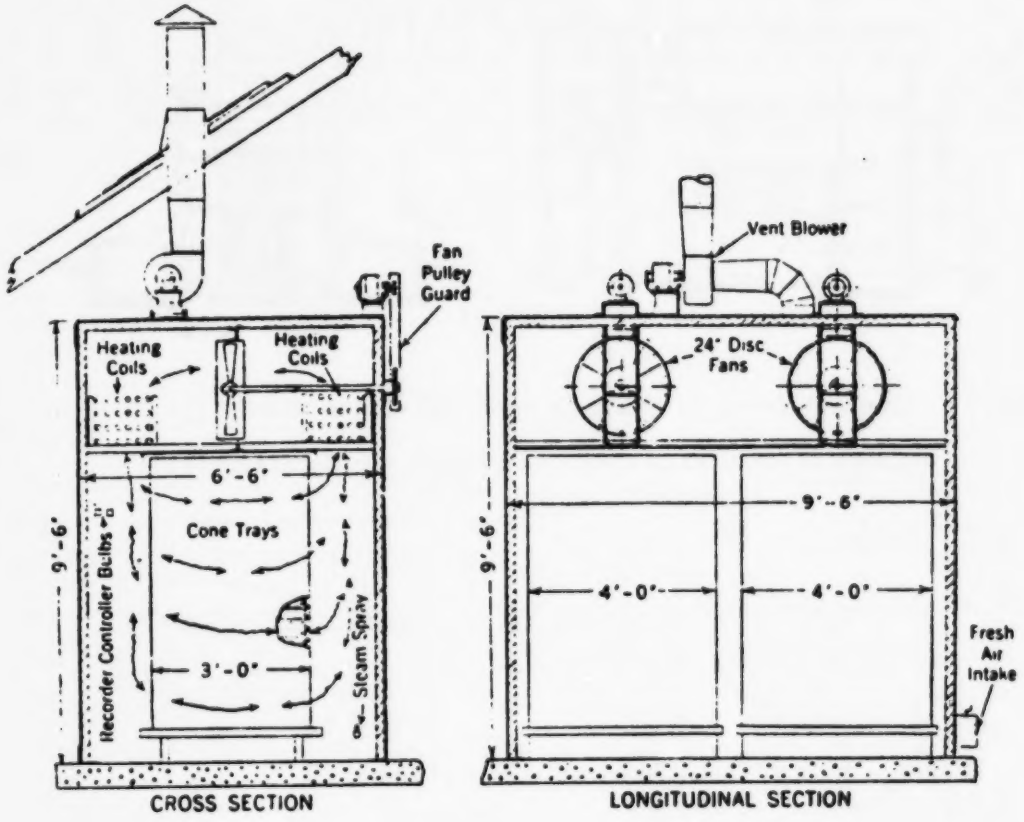



Fig. 2. Cross and longitudinal sections of a modern, automatically controlled, forced-draft, internal-fan steam-heated kiln for drying cones.

Different versions using these principles are:

WOLFGANG SEED EXTRACTION PLANT (Fig. 3) (Baldwin 1942).

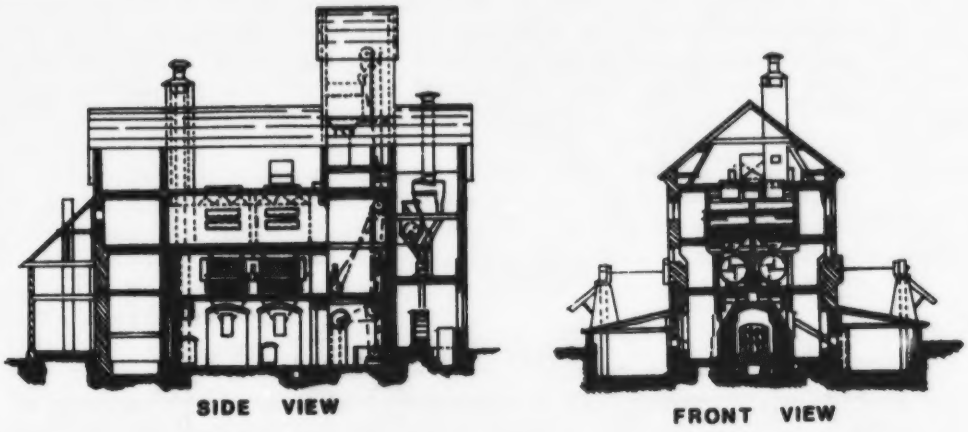



Fig. 3. Side and front of Wolfgang seed extraction plant.

MECHANICAL SEED KILN (Fig. 4) (Toumey and Korstian 1960)

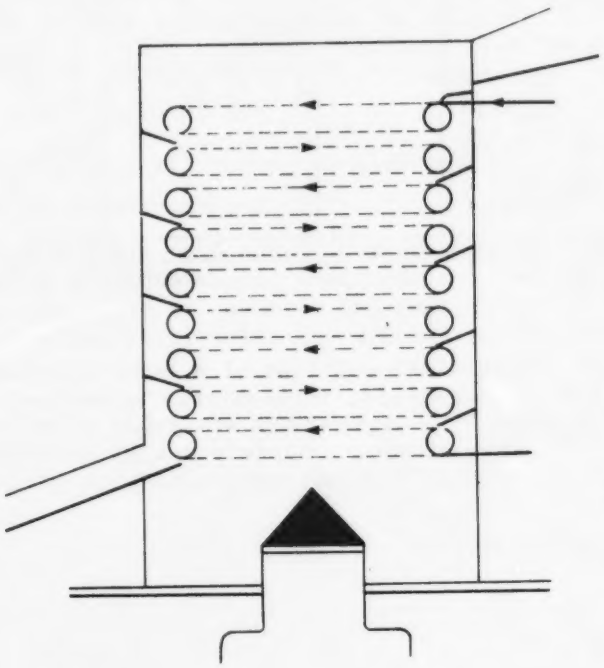


Fig. 4. Vertical section of mechanical seed kiln.

HORIZONTAL CONTINUIOUS DRIER (Fig. 5) (Gradi 1973)

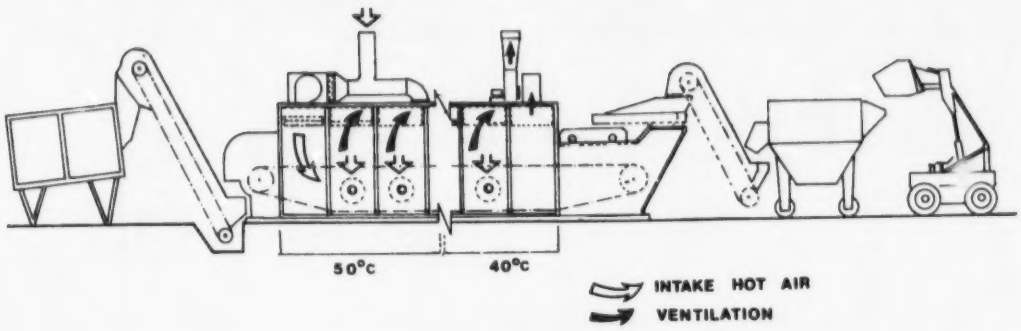



Fig. 5. Horizontal continuous dryer.

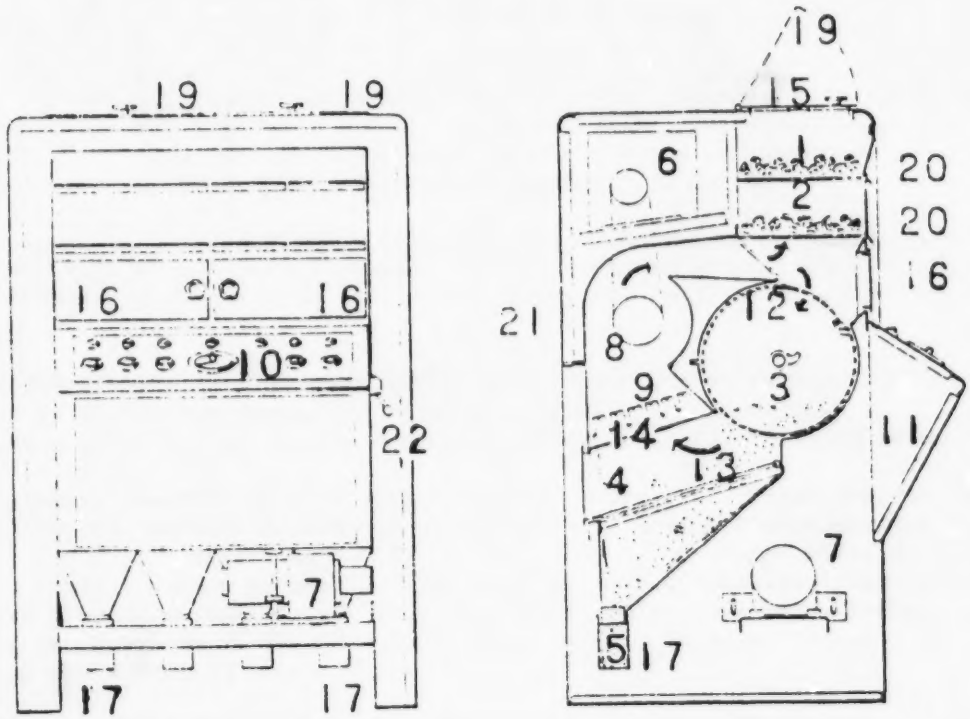
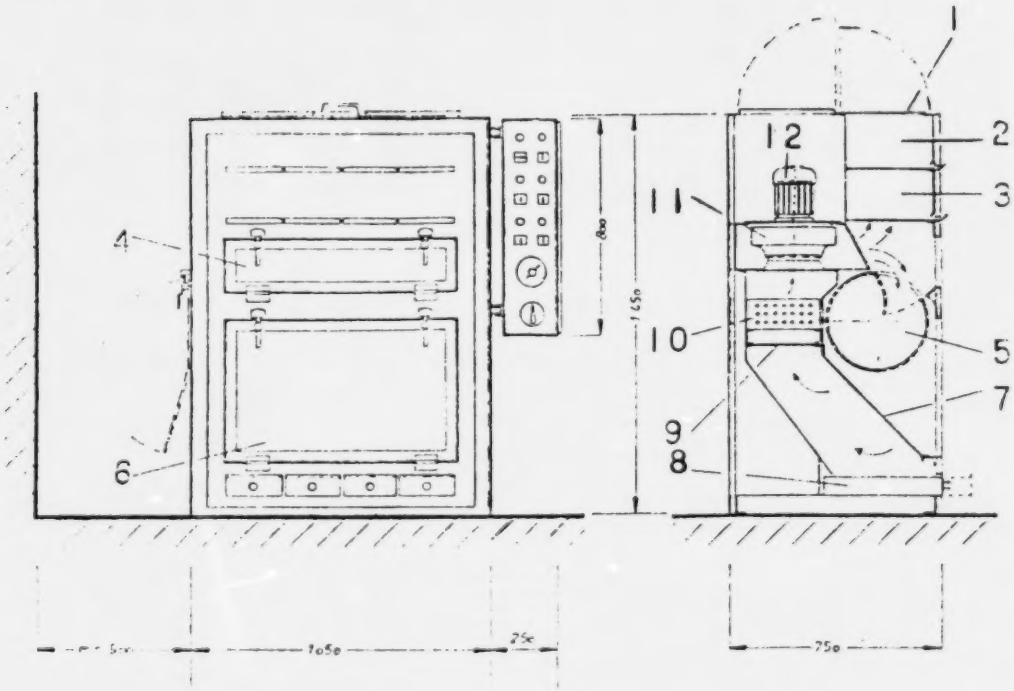



Fig. 6. Benno Schilde fully automated rotating drum kiln.

c) Rotating drum kilns are usually metal constructions with fully (Fig. 6 and 7), or partially (Fig. 8) automated processes. Pre-treatment of the cones is an important phase of this process. Usually two shelves are available for pre-drying, while the final drying is carried out in a rotating drum, which usually takes 4-6 hours. The seeds, after release, fall into a separate container which is located outside the warm air chamber. This sequence reduces heat damage to seeds and guarantees complete extraction, during the shortest period of time.




1. Loading Hatch
2-3 Pretreatment Space
4. Operating Hatch
5. Extraction Drum
6. Unloading Hatch
7. Perforated Metal Plate
8. Seed Container
9. Dust Filter
10. Heating Source
11. Ventillator
12. Rotary Drive for Drum

Fig. 7. Werner-Pfleiderer fully automated rotating drum kiln.

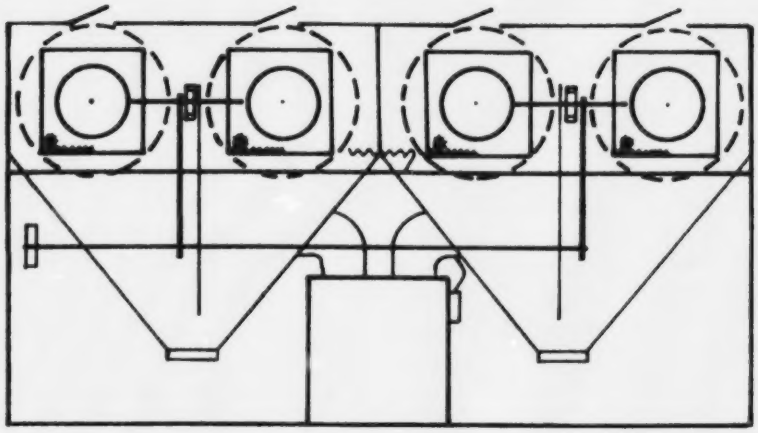


Fig. 8. End view of rotating drum type kiln at Angus, Ontario.

Their capacity is usually low (2 to 100 liters) and two or four sets of drums are generally operating, depending on the extractory. The smaller electrical types are portable, self-contained and especially suitable for small cone lot extraction (Lowman 1974).

d) Portable kilns. McConnell (1973) described a small portable kiln (Fig. 9) as a response to the seed orchard survey sponsored by the Southern Forest Tree Improvement Committee to fulfill the following requirements.

1. Economy - The initial cost had to be relatively low. A figure of $3,000 to $5,000 was judged to be in keeping with its function. Operating cost must be in line with the number of cone lots being dried.

2. Saftey - The kiln must be easy and safe to operate by relatively inexperienced people. Automatic safety controls are highly desirable.

3. Portability - Space to locate the kiln was not available at the Eastern Tree Seed Laboratory. Borrowed space would have to be used; therefore, it is very likely the kiln will have to be moved before the life of the survey is over.

4. Versatility - For the reason stated above, it was desirable that the

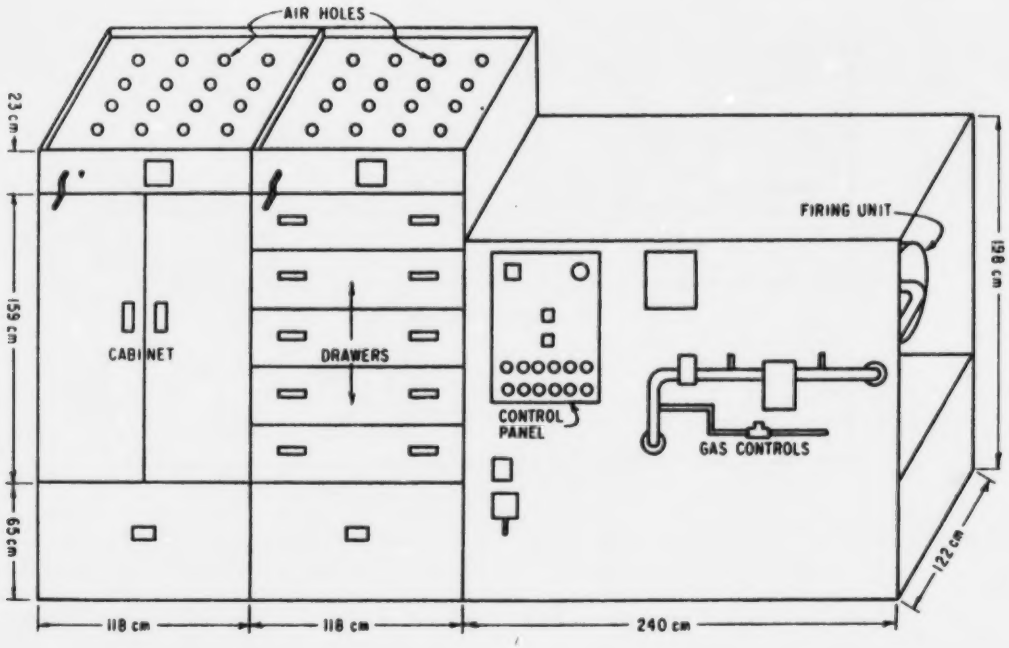



Fig. 9. Digaram of the portable kiln.

firing unit for the kiln operate on either natural or bottled gas.

5. Quantity - The minimum load size would be the 10 cone lots for the Seed Orchard Survey. A maximum load size of approximately 50 bushels (15.2 hectoliters) was chosen. The kiln must be able to handle any combination of cone lots within this range.

## CONCLUSIONS

Extraction is a critical phase in obtaining viable seeds for artificial regeneration. The duration of exposure close to the temperature causing denaturation of proteins, could create instant or latent seed damage. Mutagenic effects expressed in chromosome aberrations have been detected in stored seed samples (Simak 1973). For this reason the most efficient system should be applied when we are dealing with material intended to be used in our intensive forest mangement programs. The methods of extraction without artificial heat appear to be the least damaging. When artificial heat is used the rotating drum type models expose seeds for the shortest period of time to 54°-60°C temperature. On the other hand, with stationary type systems extraction time is the longest.

Since seed yield, seed quality including germinative energy and capacity, plant percent and seedling growth will influence roguing in seed orchards, the least damaging extraction method should be applied specifically for samples originating from seed orchards. The seed orchard program in addition to seed processing comprises many facets of different problems, from flowering to progeny testing. These problems should be approached from not only the technical but embryological, cytological, biochemical, physiological and genetical aspects.

We are dealing with complex, and unexplored phenomena, which need to be solved soon, since seed orchards are becoming essential to our future forestry practice.

Since the evolution of seed processing equipment is continuous, evolution of commercially available seed processing equipment for small seed lots should include the following objectives:

1. a) high seed quality.

   b) suitability for western conifers,

   c) economy,

   d) safety,

   e) portability,

   f) versatility,

   g) capacity,

2. Seed research on families and clones should be enlarged to obtain genetic parameters for future improvement in the next generation seed orchards.

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# SEED TESTING

C.L. Leadem

*B.C. Ministry of Forests*

*Victoria, B.C.*

## ABSTRACT

The advantages and disadvantages of bulking seed orchard seeds are discussed in relation to the observed variation in seed characteristics from individual seed orchard trees. It is stressed that cone and seed maturity, which affect seedling vigour and establishment potential, should be optimized in seed orchard production, and various ripeness criteria are compared. Since the use of standard sampling and seed testing techniques may be precluded by the small size of seed orchard lots, alternative methods, including so-called quick tests for seed viability, are described. Several guidelines for monitoring seed orchard production, and their incorporation into existing systems of seed orchard management, are also outlined.

## RÉSUMÉ

On discute des avantages et des inconvénients de la mise en vrac des graines de vergers en relation avec les variations de leurs caractéristiques, observées d'un arbre à l'autre dans les vergers. On souligne qu'il convient d'optimiser, dans les vergers, la maturité des cônes et des graines car elle influe sur la vigueur des plants et leur capacité d'implantation. Divers critères de maturité sont comparés à cette fin. Puisque l'utilisation des techniques ordinaires d'échantillonnage et d'essai des graines puet être exclue en raison du volume réduit des lots de graines produites en vergers, on décrit d'autres techniques, y compris celles qu'on appelle tests rapides de viabilité. En outre, on donne plusieurs indications pour contrôler la production des vergers à graines et on discute de leur intégration aux systèmes actuels de gestion.

## INTRODUCTION

The development of seed orchards has progressed to a point where we can evaluate past and present practices, and start planning management strategies for the future. Thus, it is appropriate at this time that we are having a workshop on seed technology for seed orchards in order that we may critically evaluate the handling of a valuable resource--seed orchard seeds.

There are a number of topics that could be discussed in the area of seed testing, but for the purposes of this workshop I have arbitrarily chosen to examine four main areas:

1. Identification of seed source--how are lots defined?

2. Determining cone and seed maturity—when to pick?
3. Testing seed quality—are special techniques required?
4. Monitoring seed orchard production—a few guidelines.

My intention with this talk is to present ideas for your consideration using past experiences or posing questions to illustrate my points. I am not setting myself up as an expert on seed orchards. My primary objective is to stimulate thinking on these and the other topics that hopefully will be explored during this afternoon's workshop session.

## IDENTIFICATION OF SEED SOURCE—HOW ARE LOTS DEFINED?

According to criteria set by the British Columbia Ministry of Forests (BCMF), the definition of seed lot varies depending upon whether the seeds were obtained from a seed orchard or from a wild stand. The identification of a source for a wild stand is broadly based upon a classification scheme which divides the province of British Columbia into 8 biogeoclimatic regions (Krajina 1969). These regions are sub-divided into a number of seed zones which for convenience and coordination closely follow forest management boundaries. Seeds collected from a wild stand within a localized area of the same seed zone are designated as an individual seed lot. Specifically, a seed lot is defined as:

> "All the seeds of a single species collected in the same year within the same provenance and obtained from trees of the same quality".

Practically speaking, seeds of the same provenance would include all the collections made within a diameter of 80 km and an elevation band of $\pm$ 150 m. The "same quality" refers to seeds obtained from trees of the same parental phenotype. A seed orchard lot is defined as:

> "All the seeds of a single species obtained from the same seed orchard in the same year".

Most BCMF seed orchards ordinarily produce only one seed lot each year although production may be divided into more than one lot if the seed orchard contains parent trees from distinctly different provenances. One high and one low elevation seed lot per year are produced at the BCMF Koksilah Seed Orchard because the orchard is comprised of trees obtained from different elevation bands within the coastal tree breeding region.

Knowing the variability of most tree species even within a small geographic area, the question arises whether our definition of a seed orchard lot is specific enough to provide a meaningful description of a seed source. Most of the trees in B.C. seed orchards are individuals derived from many different families within a broad geographic planning zone. Operationally, it may be convenient to physically consolidate all seed orchard production into a single lot, but is this practice good tree improvement management when the seeds are from genetically distinct origins or are of very dissimilar quality? For

instance, assume that cones from one tree in the seed orchard yield seeds which germinate vigourously at 95%, but suppose that cones from another tree yield seeds which germinate poorly and erratically at 55%. Should we be mixing the cones of both trees and calling the result a single lot? It is doubtful that seed orchards will realize any gains if we continue to combine good with poor quality seeds. Currently it costs ten times as much to produce a seedling from orchard seeds as it does to produce a seedling from wild seeds. It may be difficult to justify the cost of orchard seed if the quality of our "improved" seeds is the same or even poorer than seeds from wild stands.

The basic assumption behind bulking all seed orchard cones is that trees within a broad elevational band will be suitably adapted to most outplanting sites within a similar elevational band. However, we may not be justified in assuming that seed characteristics and early seedling survival are homogenous even for seeds obtained within a limited area. In a study of the genecology of Douglas-fir in an Oregon watershed, Campbell (1979) found that genetic differentiation was much larger than expected when seeds were transferred from one part of the watershed to another. He estimated that in a 3.5 km transfer between north- and south-facing slopes at the same elevation, almost 80% of the seedlings would be poorly adapted. In British Columbia, we may also be overlooking the strong intra-provenance differences that have been observed within a small geographic area (Meagher 1981)[1]. Naturally regenerated western hemlock seedlings growing at Mt. Seymour and Haney, B.C. were separated by only 32 km, yet the young trees demonstrated diverse bud set phenologies and degrees of frost hardiness. Elevation and aspect of both sites were similar, but the physiological response of the two populations was very different.

Collecting seeds from the same tree does not assure that seed characteristics will also be uniform, for even seeds obtained from a single tree can vary from one year to another. Wang (1976) found that white spruce seeds collected from individual trees over several seasons exhibited varying degrees of dormancy in different years (Table 1). Using the criterion that seeds were not dormant if germination of stratified seeds was not significantly different ($p = 0.01$) from that of unstratified seeds, Wang found seed dormancy in 25% of the trees in 1965, 33% in 1966, and 100% in 1967. Dormancy in seeds from the same parent has also been shown by others to vary in *Picea glauca* and *Pinus densiflora* (Asakawa and Funita 1966).

Bulking seed orchard seeds may present other problems. We may be inadvertently restricting our genetic base and reducing the ability of orchard seedlings to survive under changing environmental conditions. In a case reported from Oregon, the orchard manager observed that cone and seed production varied considerably between orchard trees, with some

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[1] Meagher, M.D. 1981. Research Branch, British Columbia Ministry of Forests. Unpublished data.

trees producing much more than others. Upon closer examination he discovered that the majority of the orchard seeds were being produced by a limited number of clones. Thus, the genetic material of the heavy producing clones was disproportionately represented relative to the less prolific clones. The net result is that the trees produced from these seeds could be lacking the genetic adaptability usually found in natural forest populations. Because of our present system of bulking collections, it is not possible to determine the proportion of seeds that an individual clone may contribute to total seed orchard production.

Table 1. Dormancy and Laboratory Germination Criteria of White Spruce Seed.[2]

| Tree No. | Coll. Year | Germination (%) Strat'd 3 wk | Germination (%) Un-Strat'd | Seed Dormancy Rating |
|---|---|---|---|---|
| 1853 | 1965 | 92.7 | 70.9 | ND |
| | 1966 | 82.3 | 70.5 | ND |
| | 1967 | 95.9 | 80.0 | D |
| 1857 | 1965 | 65.9 | 31.2 | D |
| | 1966 | 53.0 | 28.5 | D |
| | 1967 | 63.7 | 36.0 | D |
| 1861 | 1965 | 60.3 | 69.9 | ND |
| | 1966 | 48.4 | 54.4 | ND |
| | 1967 | 83.4 | 47.9 | D |
| 1624 | 1965 | 51.4 | 52.2 | ND |
| | 1967 | 76.6 | 47.4 | D |
| 1756 | 1965 | 37.5 | 40.9 | ND |
| | 1967 | 97.2 | 89.6 | D |
| 1855 | 1965 | 86.7 | 80.9 | ND |
| | 1967 | 94.4 | 75.4 | D |
| 1860 | 1965 | 17.9 | 58.9 | ND |
| | 1967 | 93.4 | 51.7 | D |
| 1865 | 1965 | 92.0 | 71.5 | D |
| | 1967 | 94.5 | 64.7 | D |

[2] Wang 1976.

Thus, it is strongly recommended that if seed collections are to be bulked there should at least be procedures for routinely monitoring the distribution of genetic material within all seed orchard lots.

Genetic bias can be introduced in other ways. In a study on seed sizing, Silen and Osterhaus (1979) collected seeds from 210 Douglas-fir trees belonging to 18 different families. They examined the effect of eliminating the lightest fraction by plotting seed weight distribution curves. Removal of the lightest one third of the seeds would affect 16 of the 18 families to varying degrees. Six families would lose more than 50% of their seeds, and of those six, three families would lose more than 90% of their seeds. A surprising implication of the study was the long-term effect of sizing seeds: two of the above six families were among the top families for 10-year progeny height. By sizing collections and eliminating the lightest fraction, seeds of some of the best performing phenotypes would have been discarded.

Even if convinced that seeds should not be bulked, some may argue it is not operationally feasible to collect a number of different lots in each seed orchard. However, it is apparently feasible, and presumably economic, to handle orchard seeds in very small units. In the southeastern United States, Weyerhaeuser and other commerical forest companies are collecting and planting by clones in their loblolly and slash pine seed orchards. Since they are dealing with known genotypes that have already been progeny tested, the situation is not exactly comparable to British Columbia. However, the southern pine orchards demonstrate that small lot collections can be realistically managed on an operational basis. Seed orchard production is separated into five lots primarily on the basis of elevation bands (Fashler 1981)[3]. However, it has also been suggested that other variables such as moisture, edaphic factors, and biogeoclimatic zones may be equally important.

The decision as to whether or not we bulk seed orchard seeds may ultimately come down to one of biology vs. economics. In this regard, long-term objectives should not be forgotten. We are planning now for our future forests and the question is whether we are going to opt for cheaper short-term management at the possible expense of long-term adaptability. Will progeny from bulked seeds produce vigourous, fast-growing seedlings which are suitably adapted to the climatic and edaphic conditions of our future plantations?

## DETERMINING CONE AND SEED MATURITY

In the area of maturity, seed orchards offer advantages over collecting from wild stands since picking crews and equipment are already at the harvesting site, and the developing crop can be monitored and picked at exactly the right time. However, whether obtained from wild

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[3] Fashler, A. 1981. Pacific Forest Products, Victoria, B.C. Pers. comm.

stands or seed orchards, the more mature the seeds are when harvested, the greater their vigour and establishment potential. Immature or light seeds are usually slow to germinate, more susceptible to disease, produce more abnormal germinants, and decline in germination when prechilled. The effects of collecting seeds prematurely was illustrated in a study of Douglas-fir by Olson and Silen (1975). Seed orchard lots collected early (before the third week of August) required several-fold efforts in seed extraction and germination, produced very light seeds, contained nearly all lots germinating less than 10%, suffered heavy losses after germination, required inordinate efforts to produce enough seedlings for the progeny test, and were the major cause of poor seedbed densities. By contrast, cones collected within 10 days of natural seedfall developed less mold prior to extraction, required minimal efforts in seed extraction and processing, germinated well in the nursery, and produced excellent seedlings. Olson and Silen estimated that at least 10 times the effort was required to produce seedlings with immature seeds than with seeds collected within 10 days prior to seed fall. Although exact comparisons cannot be made, the results of their study place a better perspective on the true costs of immature seeds. To quote our friend and colleague Alan Orr-Ewing, "Good seed doesn't cost--it pays".

Maturity is dependent upon a number of factors and can be very difficult to determine. Maturation is not necessarily complete when maximum dry weight is achieved. In some species, embryos may be immature and continue to develop after removal from the parent plant even though morphological maturity has been reached (Bonner 1973; Edwards 1980; Rediske and Nicholson 1965; Thomas et al. 1973). Morphological maturity is determined mostly by size, whereas physiological maturity is based primarily upon the ability of the seed to germinate when placed under favourable conditions. Rediske and Nicholson (1965) thought of maturity as a developmental process which could be separated into two stages. Maturation is the first stage and is characterized by organic accumulation, seed weight gain, and greater radiographic density of the megagametophytic tissues. The second stage is artificial storage, during which seed moisture is reduced and germinability develops.

Operational definitions of maturity may be slightly different. The criteria used by BCMF to determine cone and seed maturity are embryo length, condition of the endosperm, and cone and seed colour (Table 2). In the BCMF Koksilah Seed Orchard the criteria used to judge maturity are even more well defined (Table 3). However, maturity cannot be determined on the basis of a single criterion. The entire developmental picture must be viewed before assuming a crop is ready to harvest. Even with well defined guidelines there can be problems in assessing the maturity of a crop. In British Columbia, Douglas-fir seed orchards developed good cone crops during the very warm summers of 1978 and 1979. Under favourable climatic conditions embryos quickly reached 75% of the embryo cavity length. According to the guidelines (Table 2) they were ready to pick. However, if embryo length had been used as the sole criterion the crop would have been picked too soon. The megagametophytic tissue was soft and milky. Therefore, the crop was allowed to remain on the trees until all the tissues were mature.

Table 2. Cone and seed maturity of B.C. Conifers[4]

| SPECIES | CRITERIA | | COLLECTION PERIOD |
|---|---|---|---|
| ABIES | Embryo--75% of cavity<br>Endosperm--firm | Aa<br>Ag | Late Aug.-mid Sept. |
| | | Al | Mid-Sept.-mid Oct. |
| CHAMAECYPARIS NOOTKATENSIS | Cones--yellow to golden-brown<br>Seeds-brown, dry, hard | | Aug.-Oct |
| PICEA | Seed coats & wings-golden-brown<br>Embryo--yellow-green,75% of cavity<br>Endosperm--firm | Sw<br>Se | Mid Aug.-Sept. |
| | | Ss | Sept. |
| PINUS | Cones--<br>Coastal, shiny golden-brown<br>Interior, brown, tightly closed | | Late Sept.-Oct<br>Oct.-Mar. |
| PSEUDOTSUGA MENZIESII | Cones--green to yellow brown<br>Seed coats & wings--golden brown<br>Seeds detach readily from scales<br>Embroy--75% of cavity<br>Endosperm--firm | | Mid Aug.-early Sept. |
| TSUGA | Cones--yellow brown | Hw<br>Hm | Sept.-Oct. |

[4] Dobbs, et al., 1976.

Table 3. Cone ripeness criteria

1. Bracts should be brown.
2. Cones should be turning brown.
3. Endosperm should be opaque white, not milky or liquid (leave cut seed over-night. If much shrinkage, then not ripe).
4. Embryo should be 90% or more developed, i.e., be about as long as seed itself.

In some cases, proper storage of immature seeds can offset potential losses from collecting crops too early. Douglas-fir cones have

been successfully artificially ripened in storage when picked as early as 5-6 weeks prior to natural seed fall (Rediske 1969; Silen 1958). But after ripening treatments are effective only if seed development has reached a critical minimum level. Even under optimum conditions, seeds picked prior to this critical stage are unable to continue the maturation process in storage.

Because this critical stage can be so difficult to determine, a number of maturity indexes have been proposed to aid in the collection of cone crops. One index which may prove to be very useful to seed orchard managers is the degree-day summation. This index relates the summer temperature experienced by a developing crop to the degree of seed maturation. To obtain a good ripeness indicator, measurements should account for the variation due to latitude, elevation, and slope aspect and should be made during the months of June to August. In an Alaskan study of white spruce, Zasada (1973) calculated the heat sum from the time of pollination, then related that value to cone and seed development. He found that a minimum of 625 degree-days above 5°C was necessary before seeds were morphologically complete. In the year of the study the required heat sum was not reached until August 5. The degree-days summmation has good potential as a reliable maturity index, but the technique needs to be refined. Improving the reliability of the index by correlating degree days with other meteorological variables such as solar radiation and precipitation could result in the development of a significant management tool.

## TESTING SEED QUALITY--ARE SPECIAL TECHNIQUES REQUIRED?

Traditionally, forest geneticists have concentrated on improving phenotypic characteristics such as tree volume and form, but phenotypic selection based on mature form does not guarantee either good cone production or seed quality. In reality, the "improved" seeds of breeding programs refer to improved tree qualities. Tree breeders have not been interested in improving the physical and biological qualities of seeds. However, breeding for improved seed characteristics is not unknown. Agricultural breeding programs have already been established to improve seed qualities such as vigour, seed coat permeability, seed colour, seed size, chemical constituents, and the ability to germinate at low temperatures (Dickson 1980). Since generation times in vegetable crop plants are so much shorter, perhaps forestry and agricultural breeding programs should not be compared. But the concept of breeding for seed qualities does deserve some consideration. There are a number of tree seed traits that might be genetically improved--increased seed vigour, greater disease resistance, and improved germinability at low temperatures are just a few possibilities. Any or all of these improvements would be of immense benefit to our reforestation program.

Realistically, it will be some time before we are able to breed for improved tree seed quality. For now the relevance of seed quality for orchard managers is using quality testing to gauge the progress of the tree improvement program. Sampling and testing procedures have been explicitly defined for tree seeds (Association of Offical Seed Analysts

1978; International Seed Testing Association 1976), but there are several reasons why standard testing procedures may not be suitable for testing and monitoring orchard seeds. In the near future at least, seed orchard lots will not be very large relative to lots collected from wild stands. Thus, scarcity of orchard seeds will be a major factor restricting the amount of seeds available for testing. The intensive management associated with seed orchards means that orchard seeds will also cost more than seeds from natural production areas. Both these factors have an impact on the way seed quality is tested.

The size of seed orchard lots will likely preclude the use of the usual sampling techniques. Samplers such as seed triers cannot be used for lots less tha approximately 7 kg, therefore alternative sampling techniques will be necessary. Many sampling methods have already been devised by the International Seed Testing Association (1976) for sampling small lots. There are several which are suitable for seed orchard use;

The Boerner conical divider consists of a hopper, a cone, and a series of baffles which subdivide the stream of seeds into many small streams. The separate streams are recombined and the mixed seeds are directed through two spouts into separate collection pans.

The soil divider is built on the same principle as the conical divider, but with the channels arranged in a straight row instead of a circle.

In the random cups method, 6-8 small cups are placed at random on a tray. After preliminary mixing the seeds are poured uniformly over the tray. Seeds that fall into the cups are taken as the working sample.

The modified halving apparatus is a grid of equal-sized cubical cells. All the cells are open at the top, but every alternate cell has no bottom. Seeds are poured evenly over the grid so when the grid is lifted approximately half the sample remains on the tray. The sample is successively halved until a working sample is obtained.

Sample sizes will probably also need to be modified for seed orchard testing. The usual technique for determining sample size depends on prior knowledge of the variation of the sample. Data variability is measured by the Coefficient of Variation, easily calculated as follows:

$$CV = \frac{SD}{\bar{X}} \times 100$$

where $\bar{X}$ is the arithmetic mean of the sample data and SD is the standard deviation of the mean. Essentially, the Coefficient of Variation measures the amount of variation relative to the mean and expresses that relationship as a percentage. Once the Coefficient of Variation is known, tabulated values such as those in Table 4 can be consulted. The appropriate number of samples can be chosen so that one

is reasonably assured that the qualities being measured in the sample reflect those of the entire population. But prior to taking measurements, the variation of the data is usually unknown. However, the expected variation can be approximated by examining the variation of comparable data which has already been collected. An example may help to illustrate.

A question commonly asked is how many samples should be taken to provide a reliable estimate of seedlot germination. One must first find comparable data on which to calculate Coefficients of Variation. An examination of many germination tests conducted in the BCMF Tree Seed Laboratory shows that CV for germination data have generally ranged from 1% to 6%. Next, the sample size table (Table 4) should be consulted to find the sample size corresponding to the CV of the test data. The table indicates that at a 95% confidence level and a potential error of $\pm$ 10%, the germination test should contain at least four replicates if the CV equals 6% or less. Using the CV for similar data, this simple procedure can be repeated for determining sample sizes for any untested material. However, CV should be recalculated at the completion of the germination tests to ensure that sample sizes are appropriate for the seeds actually being tested.

Table 4. Sample size table (95% confidence): sample sizes for a range of coefficients of variation (CV) and percentage errors (PE).

| CV | Sample size: PE=1% | sample size: PE=3% | sample size: PE=5% | sample size: PE=10% | sample size: PE=15% | sample size: PE=20% | sample size: PE=25% | sample size: PE=50% |
|---|---|---|---|---|---|---|---|---|
| **** | ****** | ****** | ****** | ****** | ****** | ****** | ****** | ****** |
| 1% | 7 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| 2% | 18 | 5 | 3 | 3 | 3 | 2 | 2 | 2 |
| 3% | 38 | 7 | 4 | 3 | 3 | 3 | 3 | 2 |
| 4% | 64 | 10 | 5 | 3 | 3 | 3 | 3 | 2 |
| 5% | 99 | 14 | 7 | 4 | 3 | 3 | 3 | 2 |
| 6% | 141 | 18 | 9 | 4 | 3 | 3 | 3 | 3 |
| 7% | 191 | 24 | 11 | 5 | 4 | 3 | 3 | 3 |
| 8% | 249 | 30 | 13 | 5 | 4 | 3 | 3 | 3 |
| 9% | 314 | 38 | 15 | 6 | 4 | 4 | 3 | 3 |
| 10% | 387 | 46 | 18 | 7 | 5 | 4 | 3 | 3 |
| 11% | 468 | 55 | 22 | 8 | 5 | 4 | 4 | 3 |
| 12% | 556 | 64 | 25 | 9 | 5 | 4 | 4 | 3 |
| 13% | 652 | 75 | 29 | 9 | 6 | 5 | 4 | 3 |
| 14% | 756 | 87 | 33 | 11 | 6 | 5 | 4 | 3 |
| 15% | 867 | 99 | 38 | 12 | 7 | 5 | 4 | 3 |
| 16% | 986 | 112 | 42 | 13 | 7 | 5 | 5 | 3 |
| 17% | 1113 | 126 | 47 | 14 | 8 | 6 | 5 | 3 |
| 18% | 1248 | 141 | 53 | 15 | 9 | 6 | 5 | 3 |
| 19% | 1390 | 157 | 58 | 17 | 9 | 6 | 5 | 3 |
| 20% | 1539 | 174 | 64 | 18 | 10 | 7 | 5 | 3 |

Modified from Stauffer, 1981. (Used with permission).

# TESTING SEED QUALITY

## Quick Tests

The germination test is the most familiar method by which tree seed quality is assessed. The test is conducted in controlled environment chambers and generally takes 6 to 8 weeks to complete (Association of Official Seed Analysts 1978; International Seed Testing Association 1976). The germination test is the standard by which most other seed assessment methods are evaluated because it is an actual measure of growth, and because the results can be related to field performance. However, the test has several drawbacks—it takes almost 2 months to complete and requires at least four replicates of 100 seeds each. In the small lots likely to be encountered in seed orchards, we may not be able to spare 400 or more seeds, or we may question using so many scarce and valuable seeds just for testing. There are alternative methods called quick tests which may be as suitable as the standard test. These tests use less seeds, may even be non-destructive, and take little time to perform.

The most commonly used quick tests for tree seeds are the tetrazolium chloride test (TZ), the hydrogen peroxide test ($H_2O_2$), and the X-ray contrast test (X-C) (Leadem 1981). All three tests are based upon some special biochemical of physiological feature of the seeds.

The TZ test is a viability staining method in which cut seeds are incubated in a 1% tetrazolium chloride solution for 24 hours. Hydrogen ions from respiring tissues react with the colourless TZ solution to form a red product in the tissues, formazan. Examination of the location and pattern of staining enables the seed analyst to evaluate seed quality. While classification of completely stained or totally unstained seeds is relatively easy, intermediate staining patterns may require a very experienced analyst. However, as a general rule seeds will not germinate properly if meristematic regions such as the radicle tip or the shoot apex do not stain well.

Hydrogen peroxide ($H_2O_2$) is a growth test in which cut seeds are incubated in a 1% $H_2O_2$ solution. Oxygen is released by the breakdown of $H_2O_2$ into $O_2$ and $H_2O$, Respiration is stimulated by the increased availability of oxygen and germination occurs without the need for stratification. Using the $H_2O_2$ method, seed lot viability can be assessed within one week.

The X-ray contrast method uses X-radiography in combination with a vaporous contrast agent (such as chloroform) to stain dead and damaged tissue (Simak 1974). Differential staining of the embryo and endosperm aids the analyst in evaluating seed quality. The use of vapourous contrast agents is not always essential, for X-rays can reveal a great deal about seed development and quality without staining the seeds. Empty seeds, insect-filled seeds, aborted embryos, and seed immaturity can all be monitored with X-rays. The versatility of X-radiography makes it one of the more important tools in the field of

seed technology (Allison 1980).

Each test method has its own advantages and disadvantages, therefore individual circumstances will dictate which quick test is most suitable (Leadem 1981). The TZ test requires much skill and experience, and the procedures are time-consuming and tedious. However, proponents of the method claim that in the hands of a skilled analyst the TZ test divulges more about inherent seed characters than any other quick test (Moore 1969). The $H_2O_2$ test is technically simple and easy to learn. In addition, since evaluation is based upon physical measurement of the radicle, the $H_2O_2$ is the most objective of the three methods. The X-C method is also easy to perform. Although it is the quickest of the test methods and can be completed in 2 hours, the X-C method requires an X-ray unit which may not be readily available.

The three methods suffer from one disadvantage in common with all correlation methods. By their nature, correlation methods do not directly measure performance, but some quality or characteristic believed to be related to performance. Therefore, correlation tests cannot be regarded on their own merit until results have been compared with an accepted standard. In the case of quick tests, results should be checked against incubator germination tests before being used as the sole criterion of lot quality. This presents few problems for seed orchard managers wishing to take advantage of quick test technology; orchard seeds are not required to make the comparisons, so seeds collected from wild stands can be used for the initial tests. The tests are not difficult to perform, and regressions relating quick methods to germination tests are easily derived (Leadem 1981).

The vigour test is another technique which may be used to assess the quality of orchard seeds. Usually seed performance is evaluated under optimum conditions, but the vigour test differs from other tests in that seeds are assessed according to their ability to perform under stress conditions, such as hot or cold temperatures. Stress conditions tend to eliminate all but the most vigourous individuals, thus results are generally lower than standard test figures. However, since results are more likely to corresponds to actual nursery performance, vigour tests are considered to provide a more meaningful measure of lot quality.

## MONITORING SEED ORCHARD PRODUCTION

In any business, the presence or absence of good quality control can mean the difference between success or failure of the enterprise. An essential element of good quality control is the care with which both production and performance are monitored. Seed orchards, like other enterprises, are also responsible for achieving and maintaining the highest possible quality of their product. Likewise, success or failure of a seed orchard depends upon continual and systematic surveyance of the developing crop. However, monitoring is an activity which is too important to be left to chance. To ensure adequate supervision during all phases of seed production, monitoring must become

an integral part of seed orchard management. The previously mentioned case of the Oregon seed orchard manager illustrates the utility of continuous surveyance. Because of an established monitoring system, the seed orchard manager was aware of the situation in time to take remedial steps before a serious problem developed. After he discovered that certain clones produced a greater portion of the bulk lot, the manager endeavored to broaden the genetic base by combining the current crop with seeds produced the following year. Thus, he avoided biasing total orchard production in favour of a few heavy producing parent trees.

Cone analysis is another monitoring technique which has been developed in the southeastern United States (Bramlett et al. 1977). Orchard managers use cone analysis to check for embryo abortion, seed immaturity, insect infestation, and a number of other aspects of cone and seed development. In its present form, cone analysis may be too detailed to be of practical use in British Columbia. Cone analysis is probably better suited to southern pines which take 2 years to reach maturity, but it is the philosophy underlying the practice that is of broader significance than the actual procedure. Cone analysis is used in an interactive manner to assist the orchard manager in making management decisions. As cones mature, samples are taken at regular intervals and systematically analyzed. If the analysis reveals potential problems, the manager can prescribe remedial treatment before major difficulties arise. By means of this regular monitoring program, the manager keeps abreast of crop development throughout the production period.

Monitoring procedures could be easily incorporated into existing systems of seed orchard management. Several seed orchards already have procedures which could be modified to provide additional information regarding seed orchard production. One example is the bud survey taken in October and February of each year. The number of buds on each tree are classified into low, medium, and heavy production classes so that the relative cone production of each ramet can be determined. Bud surveys could also be used to assess whether seed orchard production is being biased towards a particular clone. In most years, cone production should be fairly uniform among clones. However, routine monitoring will ensure that the genetic base of seed orchard crops is not inadvertently being restricted. The insect survey is another monitoring technique which has already been established in seed orchards. Because of early detection, technical staff have had enough time to take protection measures and prevent major seed orchard losses from insect infestation.

The seed orchard manager should also share responsibility for monitoring the seeds after they leave the orchard. Generally, nursery performance of orchard seeds is a facet of seed orchard production that has received little attention. But again we should consider our ultimate objective, which is to produce vigourous trees of superior quality. This will not be possible unless proper attention is given to the performance of seed orchard seeds.

As a final point, it should be mentioned that all possible

factors should be examined when rating the performance of orchard seeds. A recent report documents an example of how seemingly unrelated conditions may alter the interpretation of results (Mueller et al. 1981). The study compared the performance of orchard seeds with lots collected from wild stands, then concluded from survival records that orchard seeds were more subject to frost damage. However, additional analysis showed that the apparent differences in hardiness were actually due to differences in the cultural practices employed for orchard and wild seeds. Because of its cost and scarcity, orchard seed are grown at lower densities in nursery seedbeds. When wild seeds were planted at similar densities, the stock was also more succulent and prone to continue growth late into the fall.

## CONCLUSION

In relative terms, seed orchards are in their infancy. Optimistic goals have been set for seed orchards in that they are expected to meet a major part of our projected demand for high quality seeds. Yet there are a number of essential questions in the field of seed technology that have not been addressed. While a few of these questions have been touched upon in this paper, how well seed orchards meet our expectations will depend upon the way seed orchard managers deal with and resolve these critical issues.

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# STORAGE AND UTILIZATION OF ORCHARD SEEDS

J. Konishi

*B.C. Ministry of Forests*

*Victoria, B.C.*

## ABSTRACT

Current methods of storing and utilizing tree seeds are reviewed and judged adequate for handling seed orchard collection. Emphasis is placed on using seed orchard seeds as soon as possible after collection and optimizing the production of vigorous plantable seedlings.

## RÉSUMÉ

On examine les méthodes actuelles de stockage et d'utilisation des semences d'arbres et on les déclare satisfaisantes pour la manutention des graines de vergers. On insiste sur l'utilisation la plus hâtive possible de ces semences après leur récolte et sur l'optimisation de la production de plants vigoureux prêts à être plantés.

## INTRODUCTION

In order to address the question - do seed orchard seeds require new and different technology in seed storage and utilization, I shall begin by describing the characteristics of orchard seeds in comparison to seeds collected from natural stands.

Based on early seed production experience, primarily from coastal Douglas-fir orchards, the following general characteristics can be listed:

(i) orchard seedlots are smaller than seedlots collected from natural stands,

(ii) orchard seed yields are lower than those from natural stands,

(iii) seeds originating from orchards are larger than seeds collected from natural stands,

(iv) orchard seeds can cost an estimated 4-10x more than seeds from natural stand seed collections,

(v) germination quality of orchard seeds is consistently high,

(vi) seed insects are a problem in orchards,

(vii) seed diseases are not a problem in Douglas-fir orchard seeds but may be a problem in other species such as spruce,

(viii) orchards produce seeds more frequently than natural stands,

(ix) orchard seeds have higher vigour in comparison to seeds from natural stands (e.g. rate of germination is faster),

(x) orchard seeds have higher genetic quality in comparison to seeds from average natural stands. This can be attributed to use of phenotypic selection of parent trees, use of best trees from the best provenances for parent trees, and development of clonal orchards and roguing of undesirable phenotypes based on progeny test results.

Some, but not all, of the above characteristics have impacts on seed storage and utilization practices.

Appendix I and II provide data in support of some of the above general characteristics.

In view of the high vigour and genetic quality of orchard seeds, it is important that the seeds be properly stored and handled to prevent deterioration and damage. Utilization of orchard seeds should aim at obtaining the highest possible seedling recovery.

## STORAGE

In British Columbia, all seeds for Crown land reforestation are stored at the Seed Centre in Duncan. The current inventory is 35,172 kg of which 80 kg are orchard seeds. Cumulative seed production from all orchards up to and including the 1980 crop is 302 kg.

All seeds are dried to 6-9% moisture content and placed in tightly sealed 4-6 ml polyethylene bags and placed in freezer storage at -17.6°C. Using these conditions, we have stored Douglas-fir seeds for over 25 years with no loss in viability.

The period of seed storage for the early production from orchards may be relatively short owing to high demand and low supply. As first generation orchards mature and produce seeds above demand levels, it will be desirable to bank a 10-15 year seed supply. This will then allow for replacement by a second generation orchard without disruption in seed supplies.

Storage of small orchard seedlots will generally cause increased record keeping and packaging tasks. For example, in British Columbia a different type of tag is used to distinguish orchard seedlots from natural stand seedlots.

Considering the above points, minimal problems have been experienced and are foreseen in the future in storage of orchard seedlots. It is recommended that the specifications for drying seeds to 6-9% moisture content, packaging in tightly sealed 4-6 ml polyethylene bags, and storage at -17.6°C be continued for orchard seeds.

## PREPARATION

Operational experience, based primarily in coastal Douglas-fir and Sitka spruce, has indicated that there is no need to develop special stratification techniques for orchard seeds of these species. However, this does not preclude the need to develop special techniques for other species.

## UTILIZATION

In view of the high quality and cost of orchard seeds, they should be utilized to provide the highest possible plantable seedling recovery. To optimize use-efficiency and achieve the full benefits of orchard seeds, the following recommendations are made:

(i) orchard seeds should not be used for direct seeding projects.

(ii) seed should be cleaned to obtain 90%+ germination to enable single-seed sowing per cavity for container nursery operations.

(iii) when sowing orchard seeds in bareroot nurseries, lowering the sowing density (in comparison to sowing rules for natural stand seeds) has resulted in optimizing plantable seedling recovery from the seeds used,

(iv) good orchard seeds should be utilized for seedling production and plantation establishment as soon as possible in preference to average quality natural stand seeds. The benefits of high quality orchard seeds will not be realized by retaining this valuable germ plasm stored in a dormant condition, and

(v) efficient seed utlization must be followed up with the production of vigorous planting stock, the correct matching of species to site, and establishment and management of vigorous plantations to realize the full benefits of increased wood production which can be obtained through the use of orchard seeds.

## SEED RESEARCH

Several general research topics applicable to both orchard seeds and seed collected from natural stands are listed:

(i) seed storage life should be monitored for each species. This can be done by reserving enough seeds of each seedlot to be monitored to enable periodic seed testing for a 25 yr. + period,

(ii) to optimize seed germination, further research is needed on the determination of optimum seed moisture content levels, duration and temperature during stratification for certain species such as Abies and white pine.

(iii) develop dewinging and/or pelletize seeds of western red cedar and yellow cedar,

(iv) develop sterilization and/or heat treatments to control seed bourne pests.

(v) develop precision seedling equipment.

ORCHARD MANAGEMENT PRACTICES TO IMPROVE SEED QUANTITY AND QUALITY

Early orchard seed production experience indicates that emphasis should be placed on various orchard management practices and that the orchard program should be an integral part of the tree breeding plan for a species.

(i) To maximize seed yields and minimize seed production costs:

- improve cone and seed pest control,
- improve pollination,
- improve cone induction.

(ii) Seed size and vigour:

- improve nutrition monitoring and develop cultural prescriptions to produce large, vigorous and high germination seeds.

(iii) Monitor genetic quality to measure seed improvement:

- measure both vigour and genetic quality of seeds through testing over long-term (10-20 yrs. +) by comparing orchard seeds with naturual stand seeds,
- initiate roguing of undesirable parents from orchards using progeny test data from tree breeding program.

## APPENDIX I

Comparison of Average size of Douglas-fir cone collections made from Natural Stands and Seed Orchards[1]

| Year | Average Size of Cone Collection (hl) for Coastal Douglas-fir | | | |
|---|---|---|---|---|
| | Natural Stands | | Seed Orchards | |
| | Avg. Size of S/L[2](hl) | No. of S/L's | Avg. Size of S/L(hl) | No. of S/L's |
| 1976 | 35 | 33 | 11 | 7 |
| 1978 | 32 | 15 | 18 | 13 |
| 1979 | 23 | 4 | 25 | 15 |
| 1980 | 22 | 9 | 10 | 16 |

[1] Data Source: Ministry of Forests, Seed Centre and Seed Orchard Annual Reports.

[2] Seedlot = S/L

APPENDIX II

Comparison of germination percent, seeds/gm and seed yield between A and B class seedlots

| A Class | | | | B Class | | | |
|---|---|---|---|---|---|---|---|
| Seedlot | Original Germ % | Seed/gm | Seed Yield kg seed/ hl cones | Seedlot | Original Germ % | Seeds/gm | Seed Yield kg seed/ hl cones |
| 3187 | 88 | 83 | N/A | | | | |
| 3235 | 79 | 77 | N/A | | | | |
| 3236 | 92 | 79 | N/A | | | | |
| 3237 | 89 | 77 | N/A | 2890 | 91 | 127 | .577 |
| 3252 | 84 | 85 | N/A | 2950 | 79 | 117 | .459 |
| 3284 | 96 | 86 | .531 | 2985 | 90 | 101 | .548 |
| 3285 | 91 | 89 | .080 | 3048 | 87 | 109 | .781 |
| 3286 | 83 | 93 | .176 | 3063 | 89 | 98 | .282 |
| 3295 | 84 | 77 | .295 | 3073 | 84 | 115 | .790 |
| 3825 | 83 | 82 | .190 | 3292 | 95 | 83 | .989 |
| 38226 | 81 | 94 | .218 | 3294 | 84 | 108 | .160 |
| 3822 | 75 | 90 | .218 | 3329 | 89 | 102 | .503 |
| 3826 | 84 | 88 | .162 | 3426 | 85 | 83 | .725 |
| 3830 | 87 | 87 | .187 | 3506 | 94 | 76 | .374 |
| 3837 | 90 | 85 | .381 | 3718 | 82 | 115 | .085 |
| 3842 | 87 | 85 | .411 | 3925 | 88 | 113 | .337 |
| Average | 85.8 | 85 | 0.259 | Average | 87.5 | 104 | 0.509 |

Data Source: Mueller, H., H. Hahn, B. McCutchen and C. Bartram. 1981. Review of Practices Relating to the Treatment of Seed Orchard Seed and Seedlings. Report of Technical Audit Comm. appointed by the Director, Silviculture Branch, B.C. Ministry of Forests, 46 p., (unpubl.).

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| | |
|---|---|
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| Mr. T.M. McDonough | Department Forest Research & Lands<br>P.O. Box 616<br>Grand Falls, Newfoundland, A2A 2K2 |

| | |
|---|---|
| Dr. M.D. Meagher | Research Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |
| Mr. L.K. Miller | Ministry Natural Resources<br>60 Wilson Avenue<br>Timmins, Ontario, P4N 2S7 |
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| Dr. R.P. Pharis | Department of Biology<br>University of Calgary<br>2920 24th Avenue N.W.<br>Calgary, Alberta, T2N 1N4 |
| Mr. Jack A. Pitel | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |

| | |
|---|---|
| Dr. D.F.W. Pollard<br>V. Chairman<br>1980-81 | 19th Floor Place Vincent Massey<br>Hull, Québec<br>K1A 1G5 |
| Dr. G.R. Powell | Department of Forest Science<br>University of New Brunswick<br>P.O. Box 4400<br>Fredericton, N.B., E3B 5A3 |
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| Ms. Diane Roddy | Prince Albert Pulpwood Ltd.<br>P.O. Box 1720<br>Prince Albert, Saskatchewan, S6V 5T3 |
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| Mr. S. Segaran | Forestry Branch<br>Department of Natural Resources<br>300-530 Kenaston Blvd.<br>Winnipeg, Manitoba, L3N 1Z4 |
| Mr. Dale Simpson | Maritimes Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 4000<br>Fredericton, N.B., E3B 5P7 |

| | |
|---|---|
| Mr. D.A. Skeates | Ontario Tree Improvement and Forest Biomass Institute<br>Ministry Natural Resources<br>Maple, Ontario, L0J 1E0 |
| Mr. R.F. Smith | Maritimes Forest Research Centre<br>Canadian Forestry Service<br>P.O. Box 4000<br>Fredericton, N.B., E3B 5P7 |
| M. A. Stipanicic | Min. des Terres et Forêts<br>Service de la recherche<br>2700 Rue Einstein<br>Ste-Foy, Québec, G1P 3W8 |
| Dr. O Sziklai | Faculty of Forestry<br>University of B.C.<br>Vancouver 8, B.C., V6T 1W5 |
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| Mr. B.S.P. Wang | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |
| Mr. Ronald G. Wasser | Sussex Tree Nursery<br>R.R. 4<br>Sussex, N.B., E0E 1P0 |
| Dr. J.E. Webber | Research Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |

| | |
|---|---|
| Dr. C.W. Yeatman<br>Editor-Treasurer<br>1982-83 | Canadian Forestry Service<br>Petawawa National Forestry Institute<br>Chalk River, Ontario, K0J 1J0 |
| Dr. F. Yeh | Research Branch<br>B.C. Ministry of Forests<br>1450 Government Street<br>Victoria, B.C., V8W 3E7 |
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